REPORT OF THE CHIEF OF THE BUREAU OF ENTOMOLOGY

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 30, 1932.

SIR: I submit herewith a report of the work of the Bureau of Entomology for the fiscal year ended June 30, 1932.

Respectfully,

C. L. MARLATT,
Entomologist and Chief of Bureau.

HON. ARTHUR M. HYDE,
Secretary of Agriculture.

INTRODUCTION

The changes in grouping of activities of the bureau, described in my annual report for the fiscal year ended June 30, 1931, as in the process of being carried out, were completed and put into effect in the fall of 1931 so as to avoid changes in administration during important seasonal field operations. These subject-matter changes are reflected in the reports of the divisions concerned for the fiscal year under review.

CHANGES IN PERSONNEL

The following changes in personnel have been made during the year: William H. White, who was designated acting chief of the Division of Truck Crop and Garden Insects following the resignation of John E. Graf, was by definite appointment placed in charge of the division on February 23, 1932. Percy N. Annand, who had been in field charge of one of the more important projects of the division, namely, that concerned with the investigations of the beet leaf hopper in the Pacific Northwest, was brought to Washington on June 23, 1932, to be assistant chief of the division. Ulphian C. Loftin, who had been connected with important phases of cotton-insect work under the direction of the late W. D. Hunter and had, for a number of years, been associated with outside work, relating, however, for the most part to cotton and cotton insects, was appointed to the position of assistant chief of the Division of Cotton Insects on October 7, 1931.

APPROPRIATIONS AND EXPENDITURES

The appropriations made directly to the bureau for the fiscal year 1932 total $2,863,740. In addition to this, $55,000, reappropriated to the Plant Quarantine and Control Administration, was available for investigations on fruit flies in Hawaii. In keeping with the general administrative program to reduce expenditures, and at the request of the Secretary, $150,000 of the direct appropriation was set aside at the beginning of the year as the minimum to be saved. Throughout the year an unusual effort was made to comply with the policy of curtailing expenditures. This resulted in a total saving for the year of somewhat more than $375,000, or slightly more than 13 per cent of the amount available. The appropriation made directly to the bureau provided increases totaling $179,366 for initiating new investigations or enlarging those under way. These increases may be summarized as follows:

NEW SUBJECTS

For surveys to determine the distribution and abundance of the Argentine ant, $15,000; for investigations on the control of the turnip aphid, $9,526; for

investigations on the raspberry fruit worm, $10,000; for investigations on the control of the locust borer, $8,460; for studies on insects attacking wheat in the Pacific Northwest, $5,820; for investigations on the alfalfa aphid, particularly in the western areas, $10,000; for studies to determine methods of rearing sterile flies which might be used to aid in the treatment of osteomyelitis, $10,000; for the development of sprays to aid in the control of flies in dairies, $7,940; for investigations on the wool maggot and development of methods of control, $10,000; for investigations on, and development of methods of control for, the tobacco moth, $24,240.

OLDER OR CONTINUING SUBJECTS

For investigations on baits as an aid for the control of the oriental fruit moth, $16,640; for investigations on controlling tree-killing bark beetles, $10,000; for investigations on the alfalfa seed chalcid, $1,000; for investigations on the alfalfa weevil, $8,000; for investigations and demonstrations on the control of the Mexican bean beetle in the Southwest, $10,000; for investigations on the control of the pea weevil, $10,000; for employing additional assistance to identify insects, moths, and scale insects, $8,940; for the employment of an additional entomologist to give State workers and others up-to-date information on the control of insect pests, $3,800.

FRUIT AND SHADE TREE INSECTS

As indicated under Changes in Divisional Classification of Work in the report for last year, the Division of Deciduous Fruit Insects becomes, by enlargement, the Division of Insects Attacking Fruit and Shade Trees. It now includes the unit studying insects affecting citrus and other subtropical fruits, transferred from the old Division of Tropical, Subtropical, and Ornamental Plant Insects, and, by transfer from the Division of Forest Insects, the unit working on insects affecting ornamental trees and shrubs. Both as to enemies and control measures, this latter field is closely related to that of fruit insects. The work of this division has been carried on, as last year, under the direction of the chief of bureau, assisted by B. A. Porter.

APPLE INSECTS

CODLING MOTH

The codling moth came through the winter in large numbers in almost all localities and threatened early in the season to be unusually destructive. In some important areas, especially in the Pacific Northwest, the expected serious infestations have not materialized, because of the cool weather which prevailed during the growing season. On the whole, however, the codling moth has been extremely abundant and destructive. Work on this insect, which seems increasingly difficult to control, is being conducted at four laboratories—Yakima, Wash., Vincennes, Ind., Bentonville, Ark., and Takoma Park, Md.

In the Pacific Northwest further tests have been conducted with three fluorine compounds as substitutes for lead arsenate in the second-brood and later sprays. The results obtained in 1931 with barium fluosilicate were less satisfactory than those obtained the previous year. Potassium fluosilicate, sodium fluoaluminate, and potassium fluoaluminate, on the other hand, appeared to be practically equal to lead arsenate in effectiveness. The Arkansas laboratory is devoting a great deal of its attention this year to the study of combinations of lead arsenate with oil emulsion. Such combinations have been found more effective in controlling serious infestations than has lead arsenate alone, and an effort is being made to determine the best type of oil for use with lead arsenate under Ozark conditions. Nicotine tannate, a comparatively insoluble form of nicotine, is being tested by the Vincennes, Ind., laboratory, and observations up to midsummer have indicated that this material may be of considerable value. The nicotine tannate is being prepared this season in the spray tank from a special tannic acid obtained from Chinese galls and found by other investigators to be distinctly superior to the ordinary tannic acid for the preparation of nicotine tannate.

The chemically treated bands developed by the Bureau of Entomology at the Takoma Park, Md., laboratory are, with the cooperation of other field laboratories, being rapidly adopted by commercial growers in apple sections in which serious codling-moth infestations exist.

OTHER APPLE INSECTS

Attention has been given at the Yakima (Wash.) laboratory to the tarnished plant bug, which feeds on blossom buds and newly set fruits of all kinds, causing corky scarred areas and distortions. All attempts at controlling the tarnished plant bug by the use of insecticides have failed. Thorough disking late in the fall, which destroys the hibernating bugs, has resulted in definitely less injured fruit.

Studies of the relation of insects, particularly the woolly apple aphid, to the perennial canker of apple have been continued as outlined in last year's report.

PEACH INSECTS

In contrast to last year's unusually heavy crop of peaches, the present season's crop was light in most producing sections, because of spring frosts, abnormal winter conditions, and other factors. The plum curculio infestation was likewise at an extremely low ebb in most peach sections. With the light crop and unfavorable economic conditions, however, many orchards did not receive the full complement of spray applications during the 1932 season, and this has given the curculio an opportunity to increase its numbers wherever peaches are available. The oriental fruit moth also started the season of 1932 in somewhat reduced numbers, but conditions during the growing season have been favorable in most localities, and the infestations have increased rapidly.

PLUM CURCULIO

Field testing has been continued of various fluorine compounds which gave encouraging results against the plum curculio in previous experiments. During the season of 1932 potassium fluosilicate caused considerable injury to foliage and fruit in experiments conducted at Fort Valley, Ga., and also caused moderate injury in foliage tests conducted at Harriman, Tenn. Barium fluosilicate and two forms of sodium fluoaluminate, on the other hand, caused no appreciable injury in either series of experiments.

ORIENTAL FRUIT MOTH

As in recent years, major attention has been given to two phases of the problem of the oriental fruit moth—to biological control and to the possibility of controlling this pest by the use of bait traps.

The colonization of promising oriental fruit moth parasites has been continued from Moorestown, N. J., as headquarters. Recovery collections indicate that *Macrocentrus ancylivorus* Rohwer, a valuable parasite of the fruit moth in the Eastern States, has become, as a result of the widespread colonization work of the past three seasons, unquestionably more abundant and widely dispersed than ever before. In several important peach-growing localities it is now the dominant parasite, with prospects of becoming as valuable a check on the fruit moth as it continues to be in southern New Jersey and Delaware.

Several of the parasites imported from Europe in the past two years have been liberated in various peach sections in the United States. The more important of these species are *Pristomerus vulnerator* (Panz.), *Ascogaster quadridentatus* (Wesm.), and *Trichogramma euproctidis* Gir. The search for desirable parasites was transferred during the winter from southern Europe to Japan, and the work during the current season indicates that Japan is by far the richest field for parasites yet investigated. About 30 different species have already been found there, and the total parasitism appears to be very high.

The experimental mass liberation of the egg parasite *Trichogramma minutum* Riley was continued during the 1931 season in 10 blocks of midsummer and late peaches. Small reductions in fruit infestation were obtained, but these reductions were insufficient to offer encouragement as to the value of this method of control.

The large-scale bait-trap experiments were continued through the season of 1931, repeating the large-scale tests conducted during the preceding season. In spite of the extreme lightness of the fruit-moth infestation, the results indicate rather definitely in both the Indiana and Georgia experimental areas that a reduction of 50 per cent or more in the fruit infestation is possible by baiting large areas with traps in half of the trees. Cost records have shown

that under present conditions in northern Georgia bait trapping can be conducted on a large-scale basis at a seasonal cost of $8 per acre, this providing one trap in every other tree and making full allowance for depreciation of equipment and other expenses.

Extensive studies have been made of the movements of oriental fruit moth adults in the presence of bait traps, by means of liberations of marked moths, and their subsequent recovery in the traps. Recoveries have averaged fully 50 per cent, and in many cases 75 to 100 per cent of the liberated moths were recaptured. The fact that some of the moths migrated distances considerably in excess of a mile furnishes ample proof that baiting will be effective only if all the growers within a given area maintain bait traps, or if the orchard to be protected is very well isolated from other orchards.

While the large-scale trapping experiments have been discontinued, investigations of baits are being continued at Cornelia, Ga., with the purpose of developing or discovering more attractive and effective, as well as less expensive, materials. Among the attractive aromatic chemicals which have been tested, the following four materials have given the most satisfactory results: Terpenyl acetate, oil of mace, ethyl cinnamate, and oil of anise.

SAN JOSE SCALE

Experiments were continued at Fort Valley, Ga., with the use of mineral-oil emulsions for the control of the San Jose scale on peach trees, with particular reference to injury, both immediate and cumulative. An emulsion containing 8 per cent of oil caused a moderate amount of injury for the first time in the course of the experiments, which have been under way for a number of years. The strength of oil emulsion at present recommended for the control of the San Jose scale on peach trees—3 per cent—still appears to provide an ample margin of safety.

NUT INSECTS

As in previous years, the major portion of the nut-insect funds has been devoted to investigations of insects attacking pecans. In many localities east of the Mississippi the pecan nuts failed to fill satisfactorily in 1931 because of drought conditions, and the 1932 crop varies from light in most localities to moderate, very few groves having more than 50 per cent of a full crop.

PECAN NUT CASE-BEARER

The insecticide investigations of the pecan nut case-bearer during the season 1932 have taken the form of tests of various sprays directed chiefly against the egg stage, since stomach poisons have been found ineffective in its control. In two different plats, in a lightly infested orchard, two applications of summer oil emulsions at a strength of three-fourths of 1 per cent combined with nicotine sulphate 1 to 1,000 appeared to give reductions of 95 and 100 per cent, respectively, in injury to the nuts. Nicotine sulphate 1 to 800 plus fish oil 0.25 per cent gave a similar reduction in injury.

The Albany, Ga., station has reared more than 30,000,000 egg parasites of the species *Trichogramma minutum* in the laboratory. Liberations in a pecan grove near Monticello, Fla., of approximately 6,000 Trichogramma per tree appeared to reduce the infestation by the nut case-bearer 43 per cent. One particularly valuable native larval parasite in the Texas area, namely, *Perisierola cellularia* var. *punctaticeps* Kieffer, has been found to be absent in the Georgia pecan section, and steps have been taken to introduce it into the Georgia area.

HICKORY SHUCK WORM

A study of methods of disposing of infested pecan shucks at harvest for the destruction of larvae of the hickory shuck worm showed that the composting of the shucks by placing them in a barn lot where livestock was kept was very satisfactory, since the percentage of moths emerging from material treated in this way for two and one-half months was almost negligible as compared with emergence of moths from shucks kept under field conditions. Applications of hydrated lime gave slight reductions in infestation.

OBSCURE SCALE

The investigations of oil sprays for the control of the obscure scale at Shreveport, La., have indicated that a concentration of 4 to 6 per cent of oil is necessary to give satisfactory control of this scale, the higher strength being needed in case of heavy infestations. It has been found, however, that dormant pecan trees are particularly susceptible to injury by oil sprays; and that 4 per cent of oil is all that can be applied with safety during the dormant period, unless the trees are in a vigorous, healthy condition and are growing in good soil, in which case strengths as high as 6 per cent appear to do no damage.

PECAN PHYLLOXERA

Preliminary experiments conducted in southern Louisiana in the control of a species of pecan phylloxera, *Phylloxera devastatrix* Perg., have given very encouraging results. Applications were made in the late dormant and in the so-called delayed-dormant period. The materials tested included combinations of lime-sulphur, from the dormant strength of 1 to 8 down to the summer strength of 1½ to 50, with nicotine sulphate at 1 to 800, and a combination of lubricating-oil emulsion at 3 per cent, with nicotine 1 to 800. All these combinations gave apparent reductions in infestation of 90 to 98 per cent.

PECAN WEEVIL

Further experiments during the season of 1931 have confirmed the results of earlier experiments in the control of the pecan weevil which have indicated that hydrated lime is of value in reducing infestation by this species. While the infestation in the experimental orchard was light and irregularly distributed, three applications of hydrated lime at a strength of 25 pounds in 50 gallons of water appeared to reduce the injury from 1.1 per cent to 0.35 per cent. Observations have shown that attack is inclined to be localized on individual trees. It has also been found that in the early part of the season most of the weevils are found in the lower portions of the trees. Years of light infestation appear to alternate with years of heavy infestation.

CHESTNUT WEEVIL

Experiments with the use of hydrated lime for the control of the chestnut weevils *Curculio proboscideus* Fab. and *C. auriger* Casey have been continued as outlined in previous reports. Studies are also in progress with soil treatments of various kinds, including cultivation and the use of a number of different soil insecticides.

GRAPE INSECTS

The major problem of the grape insect laboratory at Sandusky, Ohio, has continued to be the grape berry moth. Nicotine tannate, combined with certain spreaders, seems to offer a little promise as a substitute for lead arsenate. Major emphasis is now being placed upon possible modifications of cultural practices, with the idea of having the cocoons exposed during the winter period and covered with soil during the normal emergence period in the spring. The cultural treatments have resulted in a marked reduction in the first brood of berry worms, the infestation being brought to a point where one, or at most two, early applications of lead arsenate give satisfactory commercial control of the berry moth, with a reduction in the quantity of arsenical residue on the fruit at harvest time.

BLUEBERRY MAGGOT

Dusting with calcium arsenate for the control of the blueberry maggot, as worked out by the bureau laboratory at Cherryfield, Me., gave reductions in infestation in 1931 ranging from 90 to 99 per cent. In 1932, because of unfavorable conditions, the control was a little less complete. In all except heavily infested areas, which fortunately are rather rare, this treatment is sufficiently effective to permit the production of a pack practically free from maggots. These methods were used in 1931 successfully on a state-wide basis. The low

selling price of blueberries during the season of 1931, however, prevented many growers from dusting their blueberries this year. Results of further experiments indicate that in general a mixture of calcium arsenate and hydrated lime in equal proportions is about as effective as calcium arsenate used alone. Among possible substitutes for calcium arsenate, copper carbonate showed some promise. Sodium fluosilicate was decidedly ineffective against the blueberry maggot.

SUBTROPICAL FRUIT INSECTS

CALIFORNIA RED SCALE

The laboratory at Whittier, Calif., in cooperation with the Bureau of Chemistry and Soils, has continued its investigations of the varying resistance of the California red scale to fumigation with hydrocyanic acid gas. Laboratory tests have confirmed the results reported by earlier workers, indicating that there are considerable differences in the resistance to cyanide gas among the several developmental stages of the red scale. The stage known as the second molt is most resistant, and for an approximately complete kill this stage may require as much as two and four-tenths times the concentration of cyanide necessary to destroy the least resistant stages of the scale. Field tests, supplemented by laboratory studies, indicate that the stages of the red scale that are most resistant to cyanide fumigation are most susceptible to the effects of oil sprays. This difference or "selectivity" of the two treatments is probably the basis for the apparent success of the combination treatment of oil spray followed by fumigation which has developed in certain citrus-growing sections of southern California.

DATE-PALM INSECTS

The work with date-palm insects, conducted from the Whittier, Calif., laboratory as headquarters, has been continued, with particular reference to the treatment of date offshoots for the control of the Parlatoria date scale. The experimental work with heat treatments, including dry heat, moist heat, and hot-water treatments, is practically completed.

CITRUS THRIPS

Sulphur dusting at the Lindsay, Calif., laboratory has continued to give very satisfactory control of the citrus thrips (*Scirtothrips citri* Moulton). This species has been unusually abundant during the season of 1932. It is estimated that the saving to the citrus growers of central California resulting from this work is at least $330,000 annually. These studies have now been extended to include Ventura County and other southern California areas.

Not the least important of the findings to date is the discovery that properly scheduled sulphur dusting in central California is giving adequate control of the gray scale (*Coccus pseudomagnoliarum* Kuwana) in most cases, and data are accumulating which tend to indicate that this program is likewise showing possibilities for the control of the black scale in southern California.

CITRUS RUST MITE

The chief problem under investigation by the Orlando, Fla., laboratory during the past year has been the relation of the quantity of sulphur present on the foliage to the abundance of the citrus rust mite. The work thus far indicates that the rust mites are able to establish themselves when there is less than 0.05 gram of sulphur to 1 kilogram of green leaves, and that lime-sulphur increases respiration of citrus foliage by about 50 per cent. It has also been found that sulphur is given off as sulphur vapor and not as sulphur dioxide or hydrogen sulphide. This confirms the results obtained by other workers.

FRUIT-FLY INVESTIGATIONS

The Bureau of Entomology has continued to direct the research work in Hawaii on the Mediterranean fruit fly with funds allocated to the project by the Plant Quarantine and Control Administration (now the Bureau of Plant Quarantine). For the fiscal year 1933 the necessary funds have been appropriated direct to the Bureau of Entomology.

Major attention has been devoted to experiments in the sterilization of fruit by heat and by cold, in order that practical details may be available whenever needed in connection with the movement of infested fruits and vegetables, especially if the Mediterranean fruit fly should reappear in the continental United States. It has been found that an exposure of eight hours, after the inside fruit temperature reaches 110° F., is sufficient to kill 100 per cent of the larvæ in loquats, Chinese oranges, rose apples, Locuma, apples, sour oranges, navel oranges, Valencia oranges, Satsuma oranges, coffee berries, guavas, grapefruit, and mangoes—the time necessary to kill all larvæ varying with the different host fruits. The pupæ appear more susceptible to high temperatures than the larvæ.

A study of the effect of steam sterilization on avocados was started during the year. This fruit has been found very suspectible to injury by heat, and the variety Haley Late is the only one that appears to withstand sterilization.

A series of experiments has been carried out to determine the mortality of larvæ in fruit submerged in sea water. This is a problem of practical significance because of the practice of steamers of throwing overboard all infested material just before docking at the wharves. The data obtained from these experiments show conclusively that infested fruits floating ashore within 48 hours after being thrown overboard from ships at sea may serve as sources of infestation.

Further studies are being conducted with a large number of materials which might prove sufficiently attractive to the flies for use in bait materials. Extensive detailed biological studies are also under way, but will not be reported on at the present time.

IN MEXICO

Work on the Mexican fruit fly (*Anastrepha ludens* Loew) and related species has been continued at Mexico City and Cuernavaca, Mexico, in cooperation with Mexican authorities. Outstanding in importance is the discovery that nicotine sulphate is an effective poison for use in bait for the adult flies. This eliminates the use of arsenicals, which are extremely injurious to citrus fruits. The formula developed by the Mexican laboratories—molasses 10 per cent, nicotine sulphate 0.5 per cent, water 89.5 per cent—is now being used extensively by the Bureau of Plant Quarantine in its campaign against the Mexican fruit fly in the lower Rio Grande Valley.

Further experimental work with the vapor sterilization of fruit has confirmed previous results, showing that an exposure of eight hours at a fruit temperature of 110° F. is fatal to all fruit-fly larvæ within the fruit. It has also been found that with many fruits a shorter exposure period is entirely safe, and that larvæ which appear to survive certain of the shorter exposures are so weakened as to be unable to complete their development. Extensive studies have also been completed of the tolerance of larvæ in fruit subjected to low temperatures suitable for cold storage. As a result a cold-storage method was adopted by the Bureau of Plant Quarantine for the movement of fruit from Texas.

IN THE CANAL ZONE

Studies of various tropical fruit flies have been continued at the laboratory in the Canal Zone, the work being coordinated with that of the Mexican laboratories. Good results have been obtained with the nicotine sulphate bait in the control of certain species of fruit flies. It has also recently been discovered that two other materials—tartar emetic and borax—are effective poisons for use in fruit-fly baits. There seems a probability that borax may be somewhat injurious to citrus, although it may prove to be safe for use in the small quantities necessary for baiting the fruit flies.

SHADE TREE AND HARDY SHRUB INSECTS

The insects infesting shade trees and hardy shrubs have for another year been very abundant. The drought of 1930 and the lack of any marked alleviation of the soil dryness have continued both to favor some insects and to lower the vitality of great numbers of trees in the eastern part of the United States.

Because of the limited funds available for the work on this project, it has been largely restricted to correspondence and service. Identifications of insects

attacking shade and ornamental trees and shrubs, and advice on the methods of combating such pests, have been given during the past year to private home owners, estate owners and superintendents, park superintendents, city foresters, shade-tree commissions, and commercial tree workers. This identification and consulting work has grown to important proportions. On the Pacific coast some investigations were carried on, as well as service work and correspondence. Biological studies of two important bark-beetle enemies of cypress were made.

INSECTS AFFECTING MISCELLANEOUS ORNAMENTALS

Under this project the chief attention has been given to the camphor scale, with particular reference to the use of oil sprays. By means of methods developed by the cooperating workers of the Bureau of Chemistry and Soils, the quantity of oil deposited on the foliage has been compared with the percentage of kill of the camphor scale, and a high correlation between the two has been found. Studies are now under way of the influence of oil characteristics on the quantity of oil deposited and on the scale mortality resulting from the applications.

JAPANESE AND ASIATIC BEETLES

The work in this field is under the direction of C. H. Hadley.

JAPANESE BEETLE

The economic importance of the Japanese beetle is due not only to the losses which it occasions to certain food crops—early fruits, grapes, sweet corn, etc.—but also to the extent of its depredations on a great variety of ornamental plants, trees, shrubs, and annuals, and to the injury by the grubs to lawns, golf courses, etc. These latter factors, affecting every property owner, give it an interest and importance greater perhaps than those of many serious crop pests.

The spread of the Japanese beetle has been continuous and, in recent years, with increasing rapidity, and now covers with outlying colonies a good deal of the northeastern section of the United States. Leaving out the very wide area reached by isolated points of infestation, it is estimated that the area of continuous infestation at the end of the season of 1932 totals some 7,000 square miles. This area, where the Japanese beetle is practically everywhere present, includes New Jersey except the northern counties, the first four or five counties west of the Delaware River in Pennsylvania, and the State of Delaware as far south as Delaware City and Port Penn. Important areas of infestation are, however, rapidly developing in New York, Connecticut, Rhode Island, Massachusetts, Maryland, Virginia, and the District of Columbia. Outlying points where beetles have been recorded include the three northern New England States, Ohio, Michigan, and the Carolinas.

Unfortunately there is no outlook other than for the further spread of the beetle throughout the United States. In relation to such spread, either northward, southward, or westward, there seems little to be hoped for in climatic control. The prolonged summer droughts of the last two or three years have, however, shown the dependence of the insect somewhat upon soil moisture, indicating perhaps a minimizing of its future importance in the more arid areas of the United States. Sandy soils are also less favorable to the insect than mellow loamy soils, and for mass oviposition and larval abundance well-cropped grass areas, particularly house lawns, golf courses, and pastures, are preferred.

Another hopeful feature in relation to the Japanese beetle is its decrease in numbers and damage in the older areas of infestation. Much of such decrease may properly be ascribed to parasitism and action of other natural enemies, possibly including diseases. It is therefore reasonable to hope that a similar lessening of injury may ultimately follow in the newer areas of infestation.

Biological studies have been continued as a basis for control measures, particularly in relation to the various types of injury occasioned both by the beetle and by the grub. Among the important results of such studies for the year have been an improvement in the standard Japanese-beetle trap, increasing its efficiency and attractiveness; the determination that flooding lands such as cranberry bogs will destroy 75 per cent of the grubs and prevent material injury caused by fall feeding; the working out of a treatment with lead

arsenate for the beetle and grubs in winter greenhouse cultures of ornamentals; the perfecting of means to prevent serious injury to sweet corn, due to feeding of the beetles on the silk, by dusting the corn with hydrated lime, and the development of a machine for the economical distribution of this dust. Important phases of the work have dealt also with the fumigation of such fruit food products as bananas, small fruits, vegetables, etc., which may become invaded by the beetles and thus serve as a vehicle for their spread to long distances.

Lead arsenate continues to be the most effective means of controlling the larvæ in lawns and golf courses and for the latter is now in very general use. It is also the important means for the treatment of soil in nursery rows. The benefit of such treatment continues for about three years. The poison, however, for the exact requirements of quarantine, needs certain replacement to keep up the strength necessary to be 100 per cent effective against the grubs. Certain types of plants react unfavorably to this poison and other means for the protection of the soil about such plants are being studied. The hydrangeas used for forcing purposes, an important element of the nursery industry, are especially susceptible to lead poison, but it has been determined that the outdoor production of these plants can be satisfactorily conducted under wire screening during the summer months to protect the soil from egg deposition.

As to the future, the natural control of the Japanese beetle by parasites, and perhaps by disease, is the most hopeful outlook; and the effort to introduce into this country foreign parasites, notably from Japan, has been actively continued. During the year some eight shipments of such material, containing very substantial numbers of important parasites, were received from Japan. Of the many insects parasitic on the beetle and its eggs and grubs which have been imported, five are now definitely established in portions of the older areas in the United States that are infested by the beetle. Three of these are dipterous parasites (Tachinidae) and the other two hymenopterous (Tiphiidae). The full measure of success of these parasites has not yet been reached and the parasitism varies considerably in different areas and in different seasons. It is possible that some of these parasites will be more useful in the northern areas which the Japanese beetle is now reaching. The most important of the dipterous parasites is *Centeter cinerea* Ald., which is now established over an area of approximately 179 square miles.[1]

Another promising dipterous parasite is *Dexia ventralis* Ald., which in Japan seems to exercise a considerable degree of control under favorable conditions of host abundance. The important hymenopterous parasite is *Tiphia popilliavora* Roh., which has now spread over approximately 4 square miles in the Riverton area. This parasite has been liberated to date at 199 points, and it has been possible to recover female wasps in some 43 of these colony centers.

THE ASIATIC BEETLES

The so-called Asiatic beetles are recovering very rapidly from the reduction in numbers and spread due to the summer droughts of 1929 and 1930. Of these beetles the oriental beetle[2] (*Anomala orientalis* Waterh.) is distinctly a lawn pest, comparatively little damage being done by the adults feeding on ornamentals. The past season these beetles were again numerous in Westchester and Nassau Counties, N. Y., and New Haven County, Conn., and were found also to a lesser extent in Bronx, Queens, Suffolk, and Schenectady Counties, N. Y., and in Bergen, Essex, and Union Counties, N. J. The remedy for lawn injury is now standardized as lead arsenate—the same as for the Japanese beetle—and gives a satisfactory control, but involves a fairly high cost to lawn owners. If properly applied, an application of the poison will give protection for several years.

Another of the Asiatic beetles, known as the Asiatic garden beetle (*Autoserica castanea* Arrow), is an active flier and its spread has, therefore, been wider than that of the oriental beetle. The distribution of this beetle now extends from Connecticut to Virginia. Increasing in numbers during the last

[1] In the annual report for the fiscal year ended June 30, 1931, the spread of this parasite was indicated as 1,500 square miles when approximately 150 square miles was intended.

[2] Three or more different introduced beetles have been classed under the general designation "Asiatic beetles." That title includes the beetle under discussion and also the Asiatic garden beetle as well as others. To avoid confusion in common names, it seems desirable to employ for *Anomata orientalis* the designation "oriental beetle."

two favorable seasons—1931 and 1932—this insect has again become very abundant, and injury from its grubs has been more extensive the past season than in any previous year. The beetles are night fliers, and when temperatures are above 70° F. thousands of them may be seen in flight in search of preferred food plants or breeding grounds. On such flights they are attracted by electric lights, and on this indication light traps are being developed in the hope that they may furnish an important means of local control. Unlike the oriental beetle, this garden beetle is very destructive to foliage of various ornamental and other plants. The beetles are heavy feeders and in a single warm night may destroy most of the foliage of preferred food plants. The grub of this insect is a lawn pest and is subject to the same controls that are employed for the Japanese and for the oriental beetle.

CEREAL AND FORAGE INSECTS

The work on insects affecting cereal and forage crops is under the direction of W. H. Larrimer.

THE GRASSHOPPER OUTBREAK OF 1932

The unprecedented increase in 1931 of certain local types of grasshoppers, which are always present in the Great Plains States and more or less throughout the Mississippi Valley, and the resulting crop losses, practically complete over large areas, were discussed in my report for that year. It was also pointed out that the control work with poison baits was begun too late to be effective, and that when it became evident to both State and Federal forces that further large-scale poisoning for that season was a wasted effort, the determination was reached to conserve funds for surveys to locate the important egg-laying areas and for the destruction of the eggs by plowing in the fall of 1931–32, and also for baiting the young grasshoppers of the next year's brood.

In view of the outlook at that time for repetition of excessive damage for 1932 and inability of certain if not all of the States concerned to meet the emergency, announcement was made by the Secretary in a press release of August 27 that he would "recommend to Congress an appropriation for the purpose of cooperating with the States and local agencies in a control campaign next spring in areas where infestation promises to be severe."

As the season of 1931 drew to a close, it became apparent from the widespread egg deposition in progress that serious grasshopper injury threatened the crops of 1932. To obtain authentic information on this situation, the bureau in the fall of 1931, with the aid of State and local agencies, conducted a grasshopper-egg survey. This survey revealed that south-central South Dakota, including about a score of counties with the southern limit reaching into the most northern tier of counties in Nebraska, was the main focus of dangerous infestation. In addition to this, another center was found in extreme northeastern North Dakota and northwestern Minnesota embracing a dozen or more counties mostly in the Red River Valley, and that a lesser but still serious infestation prevailed in some nine counties in southern North Dakota and in seven counties in western Iowa, with the possibility of smaller areas in many States of the Mississippi Basin. The areas most seriously threatened were practically the same as those devastated by the pest in the summer of 1931.

Following the egg survey, a conference was held with State officials for the purpose of analyzing the situation and determining the needs for the grasshopper campaign for 1932. At this conference estimates were made of the application costs and amount of poison bait necessary to treat the areas in the several States known at that time to be seriously threatened with grasshopper damage. This estimate indicated approximately $3,000,000 as the cost of such control work. It was estimated that one-half of this cost would be required for the local distribution and application of the poison bait, and it was agreed that this part of the cost could be borne by the local communities and farmers concerned. It was appreciated, however, that the combined effects of two years of drought (1930 and 1931), the wholesale destruction of crops by grasshoppers in the later year, as well as other unfavorable conditions which had prevailed in many of these States would make it difficult, if not impossible, for local communities, even with such State aid as might be possible, to meet the entire expenses incident to a control campaign. It was estimated that the total amount of bait which would be required for the areas in the several States concerned would cost, including shipping charges to local distributing points

and minor administration expenses, $1,450,000, and that if the furnishing of such bait could be undertaken under a Federal appropriation an effective campaign of grasshopper control could be carried out, dividing the cost on practically a 50–50 basis. Later a complete plan of Federal and State organization was worked out, and contacts were established with the various State agricultural and technical authorities to secure the proper integration of the various units in case such joint Federal and State control work should be authorized.

In working out this program it was realized that the needs were contingent on the reaction of winter and spring conditions of 1931–32 on both the survival of the eggs and later of the young grasshoppers, but that there seemed to be little likelihood that such conditions would vary sufficiently from normal to cause any material change in the outlook. In fact, as spring approached the grasshopper experts of the bureau made a series of tests to determine the hatching ability of the eggs, and these tests showed that apparently more than 95 per cent of the eggs were in excellent hatching condition. In view of this situation and as a follow-up of the announcement by the Secretary the previous August, during December and January the department gave consideration to the need of a special control appropriation based on the proposed cooperative effort and division of costs already discussed. This estimate of $1,450,000 for bait, itemized to indicate the individual needs of the eight States chiefly concerned, was discussed with the Bureau of the Budget in January and on February 4, 1932, was approved and transmitted by the President to Congress as a supplemental estimate "for the fiscal years 1932 and 1933 to enable the Secretary of Agriculture to cooperate if necessary with various States and local agencies in controlling infestations of grasshoppers in some of the Western States during the coming summer." The appropriation bill for the department having already been acted upon by the House, this new item was discussed before the committee of the Senate on February 13 and was accepted and included in the Senate bill as returned to the House for conference.

When it became evident that early action on the agricultural appropriation bill could not be taken in the House, various efforts were made, extending through June, by the department and representatives interested in the House and Senate to secure action on the bill or to make moneys available by joint resolution, but all these efforts failed and no Federal funds were made available. About the middle of May, when it became more or less evident that Federal action could not be taken in time to be of real or full service and that the securing of any appropriation was open to doubt, letters were transmitted by the Secretary to the governors of the eight Western States concerned pointing out the status of the appropriation, the grasshopper situation, the outlook for damage, and the urgency for immediate action by the States, at least as to areas where the grasshoppers were already appearing in numbers. In Minnesota, Iowa, and Nebraska the State governments had already outlined plans for the conduct of a general campaign, and these States, followed later by North Dakota, took steps with the funds available to aid farmers in fighting grasshoppers. South Dakota, impoverished from a series of bad years climaxed with the grasshopper season of 1931, could not furnish funds for control or clean-up work, nor had farmers funds or credit with which to make purchases of bait, and little or nothing was done in that State for direct grasshopper control. Minnesota ultimately made available a total of $250,000, practically all of which was spent for grasshopper bait, with the result that the grasshopper damage was prevented or very greatly minimized. North Dakota also made expenditures of some $75,000 for bait and with similar results, and aid was extended by Iowa and Nebraska also.

In South Dakota, Nebraska, and Iowa, as well as in other States, the spring proved to be a cool and backward one, causing the grasshoppers to hatch from two to four weeks later than in 1931. The important feature, however, was that during the late spring, and particularly May and June, abundant driving rains over much of the infested area served not only to destroy many of the insects at or shortly after hatching time but also to delay the hatching of others well into or through June and, even more important, induced such an abundance of roadside and grassland vegetation where the grasshoppers were hatching as to hold them very largely to such areas long enough at least to permit the small-grain crops to mature and be harvested in good condition. The excessive rainfall and resulting destruction of young grasshoppers did not, however, extend to North Dakota and Minnesota, where lack of rain rendered the growing crops subject to the full attack of insects. In these States, therefore, the control was due practically altogether to the very extensive distribu-

tion of poison bait throughout the more heavily infested sections, which in the case of Minnesota represented a purchase of bait at a cost of nearly twice that indicated for the State in the Federal estimates.

The interesting and very happy outcome of this, possibly the greatest year of grasshopper menace from the local and nonmigratory types which the Great Plain States have ever been threatened with, is that substantial crops were produced and harvested throughout the area—the losses being spotted and unimportant as affecting the general result. The very abnormal climatic conditions which produced this result could not have been anticipated and must be looked upon as strictly providential. As already indicated, however, the saving of crops in the northern portion of the area—Minnesota and North Dakota—where other conditions prevailed, was clearly due to the poisoning campaign. In these States the results of such poisoning, even under the adverse conditions of a late application and abundance of grasshoppers, fully demonstrated the utility of this means of control. In some instances single applications of the bait covered the ground with what amounted to almost a mulch of dead grasshoppers.

Some side lights on the grasshopper situation may be worthy of record. Particularly in the field examinations in the Red River Valley northward from Fargo, and both in Minnesota and North Dakota, it seemed to be obvious that fields that had been well plowed prior to planting and had been planted early showed good stands of small grain, wheat, rye, barley, and flax, and were for the most part harvested with no, or at least with little, grasshopper injury. On the other hand, the type of farming known as "stubbling in" the grain together with late planting was usually characterized by poor or open stands of grain and lack of vigor—conditions attractive to grasshoppers, and such fields were likely to exhibit the highest damage. The important reasons for this result were that the eggs laid by the grasshoppers in the fall in such fields had for the most part survived, and the fields therefore started the season with a full complement of young hoppers, whereas in plowed fields the eggs had been destroyed and the grasshoppers reached such fields only by movement from the roadsides and other areas in June and July. In this connection it may be noted that experimental tests conducted by the bureau this season have shown that when eggs were covered with 4 inches of soil there was no spring or summer emergence.

Based on the indications of this season only, it would seem a reasonable deduction that grasshopper injury to small grains can be largely avoided by early planting in well-plowed land. Furthermore, such plowing limits the grasshopper hatch to roadside and border areas, where in bad years they can be poisoned cheaply.

Another reason may be noted why the anticipated damage to later crops was very largely escaped. During the last week in July and continuing well into August there was a very marked shifting in the grasshopper populations in the three States most concerned in the outbreak—Minnesota, North Dakota, and South Dakota. At the beginning of this period, following the substantial completion of the small-grain harvest, grasshoppers began moving from the stubble fields to adjacent crops of corn, potatoes, and flax, giving the impression that very serious damage would be done to these crops throughout the remainder of the summer. During this period, however, the grasshoppers began more or less general flights, not migratory but drifting with the winds, which resulted in their redistribution over much larger areas, with corresponding decrease in density of population. Such scattering over grasslands, uncultivated ground along creeks, roadsides, etc., resulted in the later-maturing crops, for the most part, escaping serious injury. One exception to this general rule must be made, however. In South Dakota the differential grasshopper did not become so widely dispersed as the other species and remained almost entirely in cornfields, where it caused considerable damage in some localities.

It is of interest but disappointing also that the anticipated control by parasites and diseases, while somewhat in evidence, did not result in any considerable reduction of the grasshoppers.

As to the outlook of next season, extensive egg laying began early in July, even as far north as the Red River Valley, indicating the possibility of another grasshopper year for 1933. A survey, in cooperation with the States interested, is now in progress to obtain information as to the amount and distribution of egg depositions as a basis for estimating the outlook and needs for the coming year.

THE ALFALFA WEEVIL IN CALIFORNIA

Although the alfalfa weevil has been present in the northeastern edge of California, east of the Sierras, for many years, its discovery in the northern end of the San Joaquin Valley on May 12 last, by an investigator of this bureau, came as a surprise to all concerned. Only one adult beetle was found near Tracy at that time, but subsequent surveys made by State authorities determined that the counties of Stanislaus, San Joaquin, Alameda, Contra Costa, and Santa Clara were infested. In June the insect was found to be numerous enough to inflict visible but scattering damage in the vicinity of Pleasonton, in the Livermore Valley. Steps have been taken by the bureau, in cooperation with State authorities, to introduce at once a well-established insect enemy of demonstrated utility from the vicinity of Fallon, Nev., where it is numerous. This species, *Bathyplectes curculionis* Thoms., was first brought from Europe by the Bureau of Entomology in 1911 and is now considered as one of the controlling factors in much of the older infested territory.

EUROPEAN CORN BORER

It became apparent in the winter of 1931–32 that in the Great Lakes region, owing to unusually favorable hibernating conditions, including the presence of remarkably large quantities of field débris, the European corn borer would survive the winter in greater numbers than had been the case for several years. As the spring progressed, this indication was borne out by the deposition of great numbers of eggs on the growing corn, especially in southern Michigan and northern Ohio. However, the few showers that occurred during the early part of the hatching period of the eggs were of a hard dashing nature, with high winds, and subsequently there occurred hot dry winds of an unseasonable nature. As a result of these weather conditions, large numbers of the newly hatched young corn-borer larvae were killed, which prevented in many parts of the area the extreme multiplication that impended. In spite of the excessive number of eggs laid, the unfavorable weather conditions have held the infestation throughout the 1-generation area to about the same level as for the year 1931, although this condition is by no means uniform. There was a very perceptible increase in southeastern Michigan; also in several of the important corn counties in northwestern Ohio—notably Allen, Fulton, Henry, and Paulding. In other counties in northwestern Ohio, such as Wood, Sandusky, and Seneca, reductions in the numbers of borers present have been recorded.

SOD WEBWORMS IN LAWNS AND GOLF COURSES

Although the sod webworms of the genus Crambus have long been well and unfavorably known as enemies of the hay crop and particularly of corn when planted on newly broken sod ground, it required the almost unprecedented drought of 1930–31 to reveal these insects as destructive enemies of well-kept lawns and golf greens. They appeared in great numbers on such areas in the Middle West in the summer of 1931, and in many cases quickly transformed them into brown and barren tracts. Investigators of this bureau, called into consultation, succeeded in a short time in subduing these outbreaks by the application of a modified kerosene emulsion which was found to be 100 per cent efficient and low in cost. A publication containing directions for the application of the insecticide on lawns and golf greens is in press.

INTRODUCTION OF HAWAIIAN PARASITE OF THE GRAY SUGARCANE MEALYBUG

Through the cooperation of O. H. Swezey, entomologist for the Hawaiian Sugar Planters' Association of Honolulu, several shipments of a promising parasitic enemy of the gray sugarcane mealybug, *Pseudococcus boninsis* Kuw., have been received and liberated in infested cane fields in southern Louisiana and in the Everglades section of Florida, which now sustains a considerable sugarcane culture. The parasite, *Pseudococcobius terryi* Full., was received by steamer at San Pedro, Calif., where the consignment was transshipped and dispatched by airplane to New Orleans. Here the material received careful study and care was taken to eliminate any secondary parasites before liberation was made.

HESSIAN FLY

Through the successful operation of the newly enlarged and improved Hessian fly survey conducted by this bureau there is revealed for the first time in 12 years the danger of a great outbreak of the Hessian fly extending from eastern Kansas to western Maryland and Pennsylvania. The prospect is less threatening in eastern Maryland, New York, southern Michigan, Kentucky, Tennessee, Iowa, and Oklahoma; but if the fall weather should prove favorable to its development, material injury by the pest may occur in these States as well. In order to offset this danger, preparations are being made to inform wheat growers by radio broadcast and otherwise of the steps necessary throughout the threatened area to avoid the infestation and consequent loss of crops in 1933.

TRUCK CROP AND GARDEN INSECTS

Under the reorganization discussed in the report for last year it was indicated that the old Division of Truck Crop Insects would be enlarged to include insects affecting greenhouse plants, bulbs, and other florist stock. This enlargement was made effective October, 1931, at the end of the crop season for that year. The investigations of this division have been under the general direction of William H. White.

WIREWORMS

Wireworms continued to be the most serious insect menace to general agriculture in sections of the Western States. Infestations of wireworms cover long periods; consequently, when land becomes infested, severe crop losses are likely to follow from year to year, principally to such crops as corn, potatoes, onions, beets, lettuce, beans, and various types of bulbs. The potato crop is especially susceptible to damage. The feeding marks of the wireworm may not much reduce the food value of the potato, yet the unsightly appearance of injured tubers lowers the market grade.

Investigations with soil fumigants have resulted in the discovery of some satisfactory leads for the control of these pests, particularly on crops that yield a high return per acre. The most effective treatment is carbon disulphide applied to the soil in holes 4 to 6 inches in depth and 18 inches apart. One treatment will free the land of destructive infestations of wireworms for about three years. Applications of comparatively large quantities of naphthalene to the soil also show considerable promise of reducing injury. While only preliminary tests have been made, these have been on a rather extensive scale and indicate that in order to be effective the naphthalene should be thoroughly incorporated with the soil, and an effort is being made to determine a satisfactory method of securing such incorporation.

During the past season flooding land with water when the soil temperatures were high resulted in the killing of large percentages of the worms. High temperatures increase the activity of the worms and this seems to make them more subject to drowning than when less active at lower temperatures. This discovery was the direct outgrowth of detailed laboratory experiments on temperature effects as related to the survival of wireworms when submerged in water.

Crop-rotation experiments, in relation to wireworm abundance, have yielded some interesting results. One is that a substantial reduction in the number of insects per acre can be noted after land has been in alfalfa for one year. Another is that wireworms tend to increase from year to year in lands which are planted in potatoes and which receive applications of manure. Also, the plowing under of a green cover crop does not have any effect on wireworm infestations nor is fallowing a complete remedy. This last point brings out quite clearly the seriousness of wireworms as pests of agriculture in that they are not easily starved out.

A large series of tests with poisoned baits has not revealed any very satisfactory poison. In California in one test over 12,000 beetles were captured beneath piles of malva used as traps. The females secured in such trapping averaged 60 per cent of the catch, practically all being still gravid. This means of possible control, however, needs further development.

The sand wireworm in South Carolina presents a somewhat different problem, and it has been shown that damage from this pest can be greatly reduced if the quantity of humus in the soil is increased and the winter host plants destroyed. In cases where it is feasible, fallowing the land for one season will also reduce wireworm infestations.

MEXICAN BEAN BEETLE

The Mexican bean beetle continues to be a major pest in the Eastern States. The winter survival of this insect in the Ohio Valley, and probably other areas in the Eastern States, in 1931–32 was the highest on record, being three times as heavy as in the spring of 1931, which was also a record year. The result of such survival was heavy beetle infestations, and also extension of range, especially northward into Vermont, New Hampshire, and Maine.

While our knowledge of the possibilities of the control of the bean beetle by the use of various insecticides tested at Athens, Ohio, and Norfolk, Va., has been greatly increased, spray applications of magnesium arsenate remain, for most areas and conditions, the best control.

Of the fluorine compounds, it can be stated rather definitely that, as substitutes for magnesium arsenate, they do not give protection for so long a period of time. Furthermore, satisfactory control requires heavy dosages, which add to the costs. Of these compounds, synthetic cryolite has proved to be the best substitute spray for magnesium arsenate yet tested. Barium fluosilicate as commercially produced does not give satisfactory control unless used in dosages of 4 or more pounds to 50 gallons of water. In the dust form poor control has been obtained after numerous trials with both cryolite and barium fluosilicate, apparently due primarily to the physical qualities of these materials.

An investigation was made in cooperation with the Bureau of Chemistry and Soils to determine why some brands of calcium arsenate injure bean foliage, and the conclusion was reached that atmospheric conditions are the important factors, there apparently being a direct correlation between foliage injury and humidity, the degree of "burning" being greater with lower rate of evaporation immediately following the treatment. Chemical analysis did not reveal any relationship between foliage injury and the brand of the arsenical. In the dry-land areas of the Southwest calcium arsenate can be used without risk of crop injury because of the prevailing atmospheric conditions; and that, with the cheapness of the material and its physical properties, gives it an advantage for dusting over other commercial arsenicals. Spraying is not practical in the dry-farming area.

The rearing and liberation of the tachinid parasite *Paradexodes epilachnae* Ald., which was imported from Mexico a few years ago, have been continued. All efforts have failed for carrying this parasite through the winter in the inactive stage, and it has been necessary to maintain a stock of parasites by rearings during that period. That this is the chief obstacle to better success is indicated by the recoveries of a later brood of parasites from liberations made earlier in the season, showing the possibility of their maintaining themselves through the active period of the beetle. That they do not survive the winter in the open is further indicated in that no recoveries have been made during the season of 1932 in the areas where liberations were made during the previous season.

BEET LEAF HOPPER

The beet leaf hopper, as vector of the curly-top disease, continues to be the most serious problem to the growers of sugar beet and certain other crops in the intermountain regions of the Northwest and on the Pacific coast. This insect breeds in enormous numbers in mountain canyons and other areas adjacent to cultivated districts and with the drying up of food supplies in early summer migrates in enormous numbers to beet and other crop-producing areas. Investigations which have been continued for a number of years have resulted in a determination and mapping of the more important breeding areas for the Twin Falls district, Idaho, and these studies have been intensive enough to permit the estimation, in advance of planting of the beet crop, of likelihood of heavy migrations, making it possible for planters to avoid planting in areas of possible heavy migrations and to increase their plantings where conditions appear to be favorable. During the year such studies have been extended to the beet-growing section in the Grand Junction district, Colorado, and information as to the breeding areas of the leaf hopper and its migratory movements has been accumulated which should make possible the rendering of a similar service for this district. It was possible for the current season to indicate to growers of both districts the likelihood of a very low leaf-hopper population in the wild breeding areas and the results have borne out this prediction. In the Twin Falls district a very large acreage was planted, and there is promise of one of the largest yields per acre on record. The confidence of the

growers in this service is being evidenced by the increase in acreage planted in the Twin Falls district during every year when a favorable forecast has been indicated. The continuation of this service at these two or other districts depends on the possibility of collecting sufficient data necessary for an accurate estimate of the probable leaf-hopper abundance in years when the controlling factors are less evident.

The control of the beet leaf hopper in California has been recently developed along the line of direct attack by spraying in their wild breeding areas. Owing to a particular type of fall movement and concentration of the leaf hoppers in such areas, it has been found possible to spray relatively small areas and yet obtain a very material reduction of the insects going into winter quarters. This method of control is still in the experimental stage, but the results of this year are very promising.

TOBACCO INSECTS

Poisoned baits were used against the tobacco hornworm moths for large areas during the past season in Kentucky and Tennessee to demonstrate the extent of the protection this method of control might give to tobacco plantings. The results, while not conclusive, are very promising, the fields under experimentation showing a considerably lower number of hornworms and eggs than do the check fields. Additional data are needed on the proper number of traps to use per acre and the best location of these traps for maximum protection. If this method of control ultimately proves effective, it will be useful also against hornworms on tomatoes. A valuable feature of this type of control is the reduction which may result in the use of arsenicals.

Last season's studies in Florida on the control of the tobacco flea beetle brought out quite clearly that barium fluosilicate is the most satisfactory remedy yet tested against this insect. Growers used the chemical on a rather large scale and were very enthusiastic about the results obtained. The material was tested again this year in order to check last season's results. While good control was obtained, some damage to the tobacco followed the treatments, due in all probability to the moisture conditions which prevailed during the period of treatment, in contrast with the comparatively dry period of last year. Nevertheless, by employing the "drift method" and exercising every precaution to see that a light, even coating of the chemical covered the plant, satisfactory control was secured, with little appreciable plant injury. The development of barium fluosilicate as a control for the flea beetle has resulted in a considerable saving to the shade-grown tobacco industry of Florida.

EUROPEAN EARWIG

The large-scale baiting experiments carried on under this project in the vicinity of Puyallup, Wash., have now covered a period of three years, and the season's results indicate that but 10 per cent as many of the earwigs are present in the baited blocks in 1932 as were present at approximately the same time in 1931. It seems probable that one thorough baiting of a given area will hold earwigs to a negligible number for the entire summer and leave only a comparatively small carry-over for the following season.

Studies on the food habits and economic importance of the earwig have shown that it has a varied diet ranging from flowers, plant foliage, fungi, algæ, and lichens to plant lice, scales, and other small insects. As far as can be judged at the present time, however, no control of an injurious insect is effected by the earwig.

BERRY INSECTS

Considerable information has been obtained on the usefulness of insecticides against the raspberry fruit worm and red berry mite in the State of Washington, but the results are not conclusive enough to warrant definite recommendations.

Further study of the strawberry weevil in North Carolina has demonstrated rather definitely that much damage from this pest can be prevented if clean-up measures are directed against the weevil in its overwintering quarters. The weevil hibernates near the strawberry fields in uncultivated waste lands; and if these are cleaned of all débris during the dormant period, much benefit will result and the number of insecticidal treatments may be materially reduced.

A new pest, *Cnephasia longana* Haw., known to occur in Europe, was first reported as attacking strawberries in the Willamette Valley, Oreg., in 1929, boring into the berries just beneath the cap. The spread of this insect since that time in this important strawberry-producing district has been such as to indicate that it may soon become a serious problem. The insect has also been reported as attacking blossoms of iris and flowers of other plants.

PEPPER WEEVIL

The pepper weevil continues as a serious pest in sections of California. An effort has been made to have the growers plow under the fields directly after harvest and to clean up the nightshade plant, which is the overwintering host of the weevil. In localities where this has been done, considerable reduction in weevil infestation has been effected.

The tests with fluorine compounds have shown that while these materials are quite toxic to the weevil, the reaction of the chemical on the plant is such that in some instances it reduces the yield practically 50 per cent.

CELERY INSECTS

Owing to the very mild winter of 1931–32 the celery leaf tier was particularly abundant and damaging in connection with the crop of the current season in the Sanford area, Florida. As a result of many tests with insecticides, the best control was obtained by use of pyrethrum powder diluted in equal parts with tobacco dust.

Mole-cricket injury to celery and other vegetable crops continues to increase in importance in certain sections on the eastern coastal plain, the Gulf region, and sections of Florida. The common remedy for this pest—the use of a poisoned bait—is not always satisfactory, and in its use this year it has been found that a small quantity of animal matter seems to improve its attractiveness to the crickets.

SWEETPOTATO WEEVIL

The efforts to control or even eradicate this important pest of sweetpotatoes have been continued in Mississippi and Alabama with good success. In Alabama no infestations were found during the season, and the number of infestations in Mississippi has been reduced. Excellent cooperation is being received from sweetpotato growers in this work.

SEED CORN MAGGOT

The prevention of injury to newly planted potato seed pieces by the seed corn maggot on the eastern coastal plain has been substantially worked out. What is known as suberization or corking over of potato pieces prevents maggot injury, and it has been shown quite definitely that the grower with the facilities he has at hand can secure such action and thus prevent both maggot injury and decay.

VEGETABLE WEEVIL

The vegetable weevil, an important pest of many truck crops, continues to spread in the South and in California—especially in the former region. Poisoned baits seem to offer the best solution for control, and work with these has been continued.

SPOTTED CUCUMBER BEETLE

The observations and studies on the biology of the spotted cucumber beetle have shown rather conclusively that this insect has a north, followed by a south, migration. The beetles which overwinter in the South move northward in the spring, and the generation of beetles produced in the North migrates to the South the following fall. In the South particularly this beetle causes considerable damage to a wide variety of winter vegetables. In work of this season with flourine compounds, potassium hexafluoaluminate and barium fluosilicate have been useful against the beetles on some crops.

GLADIOLUS THRIPS

During the past season a thrips, *Taeniothrips gladioli* M. and S., which has only recently been described, has caused serious damage to the gladiolus over considerable areas in the Northeastern and North Central States. The insect breeds during the summer on the foliage and when carried into storage with the corms continues its breeding on them. Laboratory tests have shown that the insect will breed throughout the winter on corms stored at temperatures of 60° to 80° F. At 50° the eggs did not hatch, although the adults deposited a few eggs at this temperature; yet larvæ already hatched and pupæ continued to develop slowly. This indicates that the commercial grower can secure control by storing his corms at 50° or slightly less during the winter. Present indications are that this insect does not overwinter out of doors but is carried to the field in the spring on the corms, hence the special emphasis on control under storage conditions. Of the fumigants tested for such control naphthalene is to be recommended because of its safety, effectiveness, and low cost. In the use of calcium cyanide, which is effective against all forms of the thrips except the egg, it is necessary to make two separate fumigations, the second to reach the hatch from the eggs after the initial fumigation. One hour's fumigation with liquid hydrocyanic acid under vacuum seems to give complete control. Of the chemical dips tested, corrosive sublimate and the organic mercurial compounds, as well as phenol, were the most effective. Heat treatments, both with hot water and with vapor heat, were very effective, and their use stimulated the corm to earlier growth.

The results of field tests for the control of the thrips on foliage, while not now complete, indicated that Paris green and brown sugar in solution gave the most satisfactory control. However, some "burning" of the lower parts of the plant followed this treatment, although the bloom was not affected.

BROAD MITE AND CYCLAMEN MITE

The broad mite (*Tarsonemus latus* Banks) has been found to be more destructive to a large number of greenhouse plants and to have a wider host range than the cyclamen mite. The broad mite seems to be on the increase, having heretofore been considered as a tropical species, occurring only occasionally in the United States. It is now being found in greenhouses in the Northwest and also affecting various crops in several greenhouses in Maryland and the District of Columbia. Laboratory tests on both the broad mite and the cyclamen mite have shown that by immersing infested plants in water at 110° F. for 10 or 15 minutes many types of plants can be freed of mites without injury. For example, no injury resulted from such treatment to cyclamen, begonia, matrimony-vine, geranium, Tourenia, *Impatiens sultana*, Achyranthes, and delphinium. Snapdragons, however, were seriously injured.

BULB TREATMENT

The work during the year shows that complete mortality of larvæ of *Merodon equestris* Fab. in bulbs is obtained with the standard hydrocyanic acid gas bulb fumigations; that is, 12 ounces of calcium cyanide or 7 ounces of sodium cyanide per 100 cubic feet for four hours. It was definitely found that hydrocyanic acid gas at the standard dosages does not penetrate sufficiently into unbroken bulbs affected with basal rot to kill Eumerus larvæ. Studies on the tolerance of the various types of bulbs to the gas show that narcissus bulbs are not injured by high concentrations. Tulip bulbs are not injured by the standard fumigation but are severely injured by long exposure and by high concentrations. Iris bulbs are not affected by the standard fumigation with hydrocyanic acid gas.

Fumigation tests with ethylene oxide gave contradictory results in so far as toxicity to the insect was concerned. Bulbs of narcissus, tulip, and iris, when exposed to 230 cubic centimeters of the fumigant to 11 cubic feet of air space for one hour, showed no ill effects from the treatment.

Tests with hot water as a means of controlling the larvæ of *Merodon equestris* removed from the bulb show that the critical temperature point lies between 111° and 112° F., and that at 111° not all the larvæ are killed when submerged for 40 minutes, whereas at 112° a complete kill was obtained in 20 minutes. A similar point was indicated in tests with Eumerus larvæ. The thrips *Liothrips vaneeckei* Priessner appeared to be completely controlled when the bulbs were submerged for one-half hour at 110°. The effect of hot-water

treatment on lily bulbs was not uniform. In some varieties severe damage followed the treatment, whereas in others a definite stimulation of growth occurred.

In the tests with vapor heat it has been determined that in order to obtain a complete kill of bulb mites and of the larvæ of *Merodon equestris* and of species of Eumerus it is necessary to expose the bulbs for two hours at 111° F. A complete kill of the grubs of the black vine weevil in the root clumps of Astilbe was obtained with 1-hour exposures at 111°. These studies show that narcissus bulbs are less susceptible to injury from this treatment than from hot water. Iris bulbs showed no detrimental effects when treated for four hours at a temperature of 111°. The exposure of dormant clumps of Astilbe to the vapor heat at 110° for one hour resulted in a decided shortening of the dormant period.

COTTON INSECTS

Investigations on insects attacking the cotton plant were conducted under the direction of R. W. Harned.

BOLL WEEVIL

The boll weevil continues to be the most important pest of cotton from middle Texas eastward and, in fact, promised for the current season unusual—perhaps unprecedented—damage. The very mild winter of 1931–32 allowed the weevil to remain active, and even in some areas to continue breeding, throughout the usual hibernation period, with the result that the carry-over to the current season was the greatest recorded in 17 years. Instead of the general average over a period of years of about 1 per cent, the survival in hibernation cages of last winter ranged from about 4 to upwards of 18 per cent, the records covering four States. Similarly, moss examinations in some 48 localities indicated the highest weevil survival to the ton of moss ever recorded, except in southern Louisiana where, however, the survival was approximately the same as in 1928, the last year of severe weevil damage. Furthermore, there were practically no unfavorable conditions in the spring and early summer to check the weevil, with the result that the actual damage to the first crop of cotton during July was very heavy. The reduction of some 25 per cent per acre indicated in the crop report issued August 1 may be ascribed very largely to the inroads made by excessive weevil numbers coupled with much less use, because of the low prices of cotton, of calcium arsenate and fertilizers. During August, however, there was a scarcity of rainfall with high temperatures over much of the Cotton Belt, with the result that many of the developing weevils in the squares were killed, and the cotton plants themselves were so checked as very largely to eliminate the possibility of late production. Practically the full weight of weevil damage for the year, therefore, fell on the squares and bolls developing during July and early August. The important exception to this was in western Texas and western Oklahoma, where an abundance of rain resulted in an unusually strong growth of cotton, which in the practical absence of the weevil promises a record crop.

Important new information has resulted from the continuation of experimental work for field control of the boll weevil. At Tallulah, La., where an effort has been made to give full protection by calcium arsenate dustings as an index to weevil damage in untreated fields, an average increase of 599 pounds of seed cotton per acre was obtained, amounting to nearly 32 per cent increase over that of untreated checks. Similar cooperative tests at Florence, S. C., gave an increase of 320 pounds of seed cotton per acre, or nearly 29 per cent increase. Other tests at three points in Oklahoma gave an increase of 423 pounds of seed cotton per acre, or nearly 52 per cent increase.

Sodium fluosilicate dust was one of the insecticides experimented with, the results being very unsatisfactory as compared with calcium arsenate, averaging from practically no benefit to a maximum of possibly 5 per cent over the checks. On the other hand, a homemade mechanical mixture of 75 per cent calcium arsenate and 25 per cent Paris green tested at Tallulah increased the yield by 569 pounds, or 29.3 per cent, per acre. This is, however, less than the increase from the use of calcium arsenate alone, already referred to.

The molasses-calcium arsenate mixture, which has had considerable vogue in past years, used by itself has failed this season to give any noticeable control of the weevil, and when one to three earlier applications have been fol-

lowed by calcium-arsenate dusting, the increase in yield has been no greater than that following calcium arsenate used for all applications. In view of the more satisfactory results obtained in other years, it is still possible that early applications followed by dusting may be desirable under certain conditions.

An interesting study of fallen squares at Tallulah indicates that nearly 71 per cent of all shedding during the season has been due to weevils. Attempts to control the boll weevil by various attractants have been continued and have so far indicated no or little utility.

The possibility of plant injury resulting from the frequent poisoning of the soil in the use of calcium arsenate for boll-weevil control seems to be limited to a small area of light sandy soil in the coastal plain of the Carolinas. At Tallulah an area where excessive quantities of calcium arsenate, many times greater than would ever be used in field dusting, had been dumped while testing dusting machinery gave normal growths when planted to cotton, corn, soybeans, and Sudan grass. An analysis of this soil showed a content of 909 parts per million of arsenic (arsenious oxide), in comparison with from 5 to 100 parts per million of arsenious oxide in the soils where the damage occurred in South Carolina. In another plat at Tallulah calcium arsenate was applied at the rate of 400 pounds per acre at the time the plat was prepared for planting cotton. Records of the plant growth, fruiting, and yield showed no significant difference between this and untreated plats. The arsenic-treated plat produced 2,457 pounds and the untreated produced 2,571 pounds of cotton per acre. Soil samples from the treated plat contained 225 parts per million, and the untreated 61 parts per million of arsenious oxide. Leaves, stalks, roots, and lint of the cotton from the treated plat contained considerably more arsenic than did those from the untreated plat.

These investigations are being continued, and tests are being made also of a number of new insecticides developed by the Bureau of Chemistry and Soils for boll-weevil control. Although there is at present no known substitute as satisfactory as calcium arsenate for weevil control when applied as recommended by the Bureau of Entomology, the results secured with other insecticides justify further experiments.

PINK BOLLWORM

Next to the boll weevil, the pink bollworm presents the most serious menace to the American cotton crop. So far it has been possible to limit any continuing foothold or opportunity for commercial damage of this pest to the valley of the upper Rio Grande in Texas and New Mexico, where, owing to adjacent cotton growing in Mexico and the certainty of reinfestation, eradication operations have been inadvisable.

The pink bollworm has occurred also in very small numbers in limited areas in western Texas, in New Mexico, and in Arizona, all under quarantine restrictions, and adequate control measures have been enforced, beginning at the gin, which it is believed have both kept the infestation down to the vanishing point and eliminated risk of these areas being a source of spread of the pest.

The notable outbreak in this area was the extensive invasion of this insect, discovered some two years ago, in the important cotton-growing area of the Salt River Valley of Arizona. The outlook now is that this invasion has been cleaned up by the activities of the Bureau of Plant Quarantine in cooperation with the authorities of that State.

The latest threat of this insect was in its discovery during this year in the southern part of Florida. Infested bolls had been sent to the department which, on reaching this bureau, were immediately determined as containing the pink bollworm. Full information was the same day sent to the Bureau of Plant Quarantine, and the authorities of the Florida State Plant Board were notified through one of its officials who happened to be in Washington at the time. An investigation of the situation was at once undertaken by the Bureau of Plant Quarantine, in which the Bureau of Entomology cooperated. Intensive clean-up operations were immediately instituted by the Bureau of Plant Quarantine, in cooperation with the State authorities. The surveys disclosed rather widespread infestation in southern Florida, but fortunately there were no commercial plantings of cotton in the area concerned, all of the infestations being confined to small experimental fields, dooryard plants, and wild cotton. Wild cotton grows as a perennial as far north as the frost line, including many of the Keys, and thus constitutes the major problem in the eradication effort.

The valley of the upper Rio Grande, and notably the Big Bend, is the only district in this country where the pink bollworm has increased to the point where it is a real factor in commercial cotton production. In this district the 1932 infestation has been heavier than ever before, following a considerable increase in 1931. The heavy flood of the Rio Grande early in September, 1932, has greatly complicated the pink-bollworm situation. There is danger that cotton bolls with living worms in them may be carried down the river to cotton-growing districts and establish new infestations.

Means of controlling the pink bollworm are being studied in cooperation with the Texas Agricultural Experiment Station at the field headquarters maintained by the bureau at Presidio, Tex. The bureau is also cooperating in such studies with the Defensa Agricola of the Mexican Department of Agriculture at Tlahualilo, Durango, Mexico. The important control measures being investigated are the destruction of the overwintering larvæ by cultural control (early fall clean-up of the stalks and bolls, deep plowing, followed by flooding), insecticides, and parasites. Good results were obtained by raking and burning stalks and trash. None of these methods, however, has been adequate to prevent the possibility of damage to the following crop.

As to control by parasites, it has not been possible to get any additional shipments of the East African parasite, but, on the other hand, two species of European corn borer parasites have been sent to the Presidio laboratory in the hope that they might attack pink bollworm larvæ, inasmuch as each of these species has been recorded as attacking the pink bollworm in the Old World. The parasites in question are *Microbracon brevicornis* Wesm. and *Exeristes roborator* Fab.

Biological studies conducted at Presidio during last year indicated that six complete generations of the pink bollworm may be expected in squares, with an average developmental period of 26 days. The development in bolls is slower, averaging 33 days, and, beginning later in the season, gives opportunity for three complete generations and a partial fourth. A large percentage of the larvæ developing in bolls are the long-cycle or overwintering stage. It has been determined that the principal means of natural spread is by migration of the fall generations, although this year for the first time at Presidio a small spring migration was noted of moths coming from the overwintered larvæ.

THURBERIA WEEVIL

This weevil continues to be a potential menace to the cotton growers of Arizona and adjoining States. It is gradually adapting itself to cotton and in 1931 caused more damage than in any previous year. Every field in the Tucson district in 1931 was found to be infested, the percentage of weevil-infested bolls ranging from 0.6 to 15.2 per cent. The importance of the Thurberia weevil to cultivated cotton is greatly heightened by the fact that there is very little winter killing of the insect either in Thurberia or in cotton. The survival of the cotton boll weevil does not much exceed 1 per cent of the numbers entering hibernation, but the Thurberia weevil exhibits a survival of upward of 80 per cent.

COTTON FLEA HOPPER

The cotton flea hopper, although the smallest of the leaf bugs that injure cotton, is considered by cotton growers in parts of several States as their most serious insect problem. This insect seems to be more injurious in the Gulf coast district of Texas than elsewhere, and damage from it reached a high point there during 1932. Studies of this insect and also of other hemipterous insects having similar habits have been continued during the year. The principal damage of the flea hopper, and of the other insects referred to, is to the squares, usually when they are quite small, the feeding punctures of these insects causing them to fall. This damage, especially by the larger sucking hemipterous insects, may extend to the fully developed squares and bolls as well. These insects migrate to cotton in the spring or early summer from other vegetation, the flea hopper chiefly from croton.

A large number of insecticides have been tested for the control of flea hoppers and other sucking insects, the best success being obtained with the use of sodium fluosilicate or of sulphur, the latter increasing the yield by 33 per cent, or 256 pounds of seed cotton per acre.

COTTON LEAF PERFORATOR

The cotton leaf perforator, a migrant from the Thurberia plant, is an important pest near the Mexican border in southern California. It occurs as far north as Riverside and extends eastward across southern Arizona, New Mexico, and Oklahoma, into the western edge of Louisiana and southward to include most of Texas. The areas of commercial damage are confined to the Imperial, Yuma, and Salt River Valleys. In the Imperial Valley considerable benefit has been derived from the adoption of the bureau's recommendation of discontinuing the cultivation of volunteer cotton, together with the adoption of better cultural practices. Control by means of insecticides is still in the experimental stage.

BOLLWORM

The bollworm has been the subject of cooperative investigations with the Texas Agricultural Experiment Station. This insect is quite variable in its injury to the cotton plant. While more or less present the past season throughout the entire cotton-growing region, the moths of this insect were abundant in northwestern Texas in cotton. The field studies, however, indicated considerable mortality in the egg stage, as well as destruction of eggs and young larvæ by predacious insects.

MISCELLANEOUS INSECTS

Biological studies of the field cricket, sometimes a serious cotton pest, have been continued. The cotton root louse caused an unusual amount of damage during May and June, 1932. Thrips were also more abundant than normally in some sections. In the Yuma Valley of Arizona the salt marsh caterpillar defoliated much of the cotton in the fall of 1931. Several species of Pentatomidæ injured the cotton in the Big Bend district so badly that 10 to 15 per cent of the bolls were unpickable in many fields. Unidentified lepidopterous larvæ, which seem to be new as cotton pests, were reported injuring bolls and boring into the stems of wild cotton in southern Florida. The West Indian gall mite (*Eriophyes gossypii* Banks), a serious pest of cotton in the West Indies, was recorded on cotton in Florida for the first time. The cotton leaf worm appeared in small numbers in Texas early in the season, but did not become abundant enough anywhere to cause noticeable damage.

The collection of insects in the upper air by airplanes, which has been conducted over a period of years, was discontinued on October 31, 1931.

INSECTS AFFECTING FORESTS, INCLUDING THE GIPSY AND OTHER MOTHS

The work in this field is under the direction of F. C. Craighead.

Again the extension of services to Government agencies administering timberlands, and to some extent to private owners, formed one of the major activities of the Division of Forest Insects. Many bark-beetle infestations on national forests and national parks were surveyed, losses estimated, and recommendations for methods of control and estimates as to the cost of control operations made. In the case of some of the larger projects an entomologist was available during the operation to give advice on questions of a technical nature.

WESTERN PINE BEETLE

As is past years the greatest amount of damage has been in the western forests and was due to bark beetles. Owing to increasing losses from the work of the western pine beetle in California, a regional survey of the California forests, directed by the Bureau of Entomology and financed in part by the United States Forest Service and the University of California, was initiated. Six hundred and twenty-five thousand acres of ponderosa pine were examined. In two large areas—one in northeastern California and the other in the Sierra Nevada—losses exceeded 8 per cent of the total stand. The total loss for the State was about 1,250,000,000 board feet for 1931. The same insect in the Pacific Northwest is estimated to have destroyed 600,000,000 board feet.

One phase of this survey, as it was carried out during the season, consisted of a study of the periodicity of bark-beetle outbreaks, an analysis of the factors causing them, and a study of the effect of the losses on the forest resources of the region. Data from sample plots, established in different parts of the

region, will serve as a basis for the analysis of stand and growth conditions and for the correlation of these factors with the rise and fall of insect infestations. As the annual records accumulate in this study, it is expected that the susceptibility of certain forest areas to bark-beetle damage can be recognized and predictions made as to future infestations.

CONTROL WORK

Control work against the western pine beetle was conducted by both the Forest Service and the National Park Service with the advice and cooperation of the Bureau of Entomology. The National Park Service spent $6,500 on control work in the Yosemite and Sequoia National Parks, checking the losses; but as adjacent areas were not treated, only temporary benefits can be expected.

The Forest Service spent $21,250 in the Stanislaus and Sierra National Forests and $14,740 in northeastern California, $10,000 of which was contributed by private timber owners.

THE MOUNTAIN PINE BEETLE

The mountain pine beetle continues its widespread devastation in the northern Rocky Mountain and Pacific Coast States. It is estimated that it killed 12,000,000 lodgepole pine trees in addition to large numbers of western white pine and some ponderosa pine in 1931. In the lodgepole pine stands of the Pacific States and in the white pine stands of the northern Rockies considerable headway has been made in its control, as is also the case in some of the less heavily infested lodgepole pine stands.

CONTROL WORK

Control work was conducted by the Forest Service and National Park Service, with the Bureau of Entomology cooperating with technical advice and assistance. In California two small operations were conducted by the Forest Service, but largely with private funds, near Lake Tahoe and Echo Lake at a combined cost of $2,950. At Crater Lake National Park $11,027 was spent in treating 15,767 lodgepole pine trees, with very successful results. A similar operation in Mount Ranier National Park reduced the infestation from 1,030 trees to less than 200.

In the northern Rocky Mountain region control work against this extremely serious enemy has been continued both in lodgepole and in white pine forests. Three years of control work in the Coeur d'Alene National Forest at a total cost of $220,000 has resulted in the preservation of the valuable white pine stands of this forest. The fourth year of intensive control work against a more scattered infestation in the white pine of the Kootenai Forest, at a total cost of $71,000, has preserved this valuable commercial timber from destruction. In lodgepole-pine stands, control in the Madison, Shoshone, Targhee, Teton, Wyoming, and Caribou National Forests, and in Yellowstone and Glacier National Parks, at a total cost of $206,000, has contributed to the protection of these potentially valuable timber stands and recreational areas.

OTHER WESTERN BARK BEETLES

A number of other western bark beetles have been investigated to determine their economic importance and to devise methods of control based upon a thorough study of their life history and habits. Among these may be cited the fir engraver beetle (*Scolytus ventralis* Lec.), which is largely responsible for the death of the fir tree, which, while of little value as a source of timber, is much prized in recreational areas. Another important enemy receiving attention is the Douglas fir beetle, an important enemy of this tree in drier sites.

A 3-year study of insects breeding in logging slash in the ponderosa pine forests of Oregon and Washington has just been completed. The results show that such insects do not usually produce good broods in slash and that such as do increase in this material are not a menace to living trees in this region.

THE HEMLOCK LOOPER

A very destructive outbreak of the hemlock looper in the spruce-hemlock forests of southwestern Washington killed approximately 162,000,000 board feet of timber on 32,000 acres between 1925 and 1931. An attempt was made to

control this pest by dusting the worst of the area from an airplane; the expenses, which amounted to about $15,000, being borne by the State of Washington, Pacific County, and private owners. This bureau furnished technical assistance and studied the results in the field. The reduction obtained averaged about 45 per cent, but some areas showed a kill in excess of 80 per cent.

EASTERN WORK

In the eastern field the investigative work upon the southern pine beetle has been continued at Asheville, N. C., and the investigations on the white pine weevil and other insects at the New England station.

In the Central States an investigation of the locust borer was begun during the year, in cooperation with the Central States Forest Experiment Station, Columbus, Ohio. The field season was confined chiefly to the establishment of sample plots. Analysis of the sample-plot data collected during the season suggests the following tentative conclusions: (1) A close correlation between lack of vigor of the individual tree and locust-borer damage; i. e., the more vigorous the tree, the less the damage; (2) a negative correlation between crown density and crown class (dominance) and locust-borer injury; and (3) a close relationship between composition of the stand and borer injury, mixed stands being comparatively immune to serious injury by the borer. It is planned to continue and extend the locust-borer investigation during the 1932 field season in an attempt to obtain further information on points upon which there was some question as to cause and effect being confused and to substantiate, by additional data, points where definite relations appear to exist.

FOREIGN WORK

One of the two entomologists who have been conducting work in Europe, with headquarters in Budapest, Hungary, returned to the United States in September, 1931. As one of the results of the studies that he conducted in Europe, he has been able to point out why some of our efforts to establish *Lydella nigripes* Fall., a tachinid fly parasitic on the gipsy moth and the brown-tail moth, have not been successful. It had been supposed that it was this species that had been secured in large numbers from the pine geometrid, *Bupalus piniarius* L., in Europe, but it is now known that this species is *L. piniariae* Hart., previously considered synonymous with *L. nigripes*. *L. piniariae* practically refuses to attack gipsy-moth and brown-tail moth larvæ. The other entomologist remained in Europe during the year for the purpose of collecting and shipping parasites to the station at Melrose Highlands, Mass. Parasites of the gipsy moth, satin moth, Europoan pine shoot moth, larch case-bearer, and *Phyllotoma nemorata* Fall. (a sawfly that mines the leaves of birch) were secured from Hungary and Austria.

STUDIES AND COLONIZATIONS OF PARASITES

The usual sample collections of larvæ and pupæ of the gipsy moth made in the infested New England area during the summer of 1931 indicated that, of the important parasites issuing from these stages, *Apanteles melanoscelus* Ratz. and *Sturmia scutellata* R. D. were considerably less effective than during the previous summer. The other important parasite, *Compsilura concinnata* Meig., occurred in these collections in about the same proportion as in the previous year, while field observations showed the important predacious beetle *Calosoma sycophanta* L. to be less abundant, and collections of gipsy-moth egg clusters made during the winter of 1931–32 showed a smaller percentage of the eggs to be parasitized by *Anastatus disparis* Ruschka than was the case of similar collections made during the previous winter. This decrease in percentage of parasitism was probably to be expected, since it is generally believed that percentage of parasitism is lowest when the host is at a low ebb, as was the case with the gipsy moth during the past year in all the infested territory except southeastern Massachusetts. According to the Bureau of Plant Quarantine, there was less defoliation caused by the gipsy moth during the summer of 1931 than for several years, and the trees in most of the area were practically free from gipsy-moth feeding. Defoliation was severe in the counties of Bristol, Plymouth, and Barnstable, Mass.

Approximately 47,000 adults of *Phorocera agilis* R. D., a tachinid parasite of the gipsy moth, that issued in the spring of 1932 from puparia received from Europe in 1931, were liberated. The species was again recovered from a

locality where it was put out in 1927 and 1928, but only in small numbers, and has not been recovered from the vicinity of other colony sites. About 2,400 adults of *Sturmia inconspicua* Meig. and 1,500 adults of *Carcelia separata* Rond., both tachinid parasites of the gipsy moth, were also liberated.

Field collections of satin-moth larvæ indicate that two hymenopterous parasites (*Eupteromalus nidulans* Thom. and *Apantelcs solitarius* Ratz.) introduced from Europe have become rather important enemies of this pest.

The species of parasites received from Europe during 1931 and colonized in the northeastern part of the United States were as follows: Four species of Hymenoptera as enemies of the European pine shoot moth, one hymenopteron as enemy of the larch case-bearer, and three species of Hymenoptera as enemies of *Phyllotoma nemorata* Fall.

Results obtained from the introduction and liberation of *Chaetexorista javana* B. and B., a tachinid parasite of the oriental moth secured from Japan in 1929 and 1930, have been encouraging. Collections of cocoons of this moth made in the spring of 1932 indicated parasitism ranging from 1.5 to 42.1 per cent.

SHIPMENTS OF PARASITES FROM MELROSE HIGHLANDS, MASS.

During the year parasite material has been secured through field collections made in New England and sent to the State of Washington and to Canada and England; the adult parasites secured from this material are to be liberated in an attempt to establish the species as factors in the control of certain insect pests. *Compsilura concinnata* Meig. was shipped for colonization as an enemy of army worms and cutworms in Barbados, British West Indies, and of the satin moth in Canada and the State of Washington; *Apanteles solitarius* and *Eupteromalus nidulans* were sent to the State of Washington as enemies of the satin moth.

A large shipment of oriental-moth cocoons was sent to England. These cocoons contained the immature stages of *Chaetexorista javana*, recently introduced and established around Boston. The parasites were desired for liberation in Ceylon to assist in the control of a lepidopteron injurious to tea.

BACTERIAL AND FUNGOUS DISEASES

Cultures, presumably of *Bacillus disparis*, and gipsy-moth larvæ supposed to have died of an infection of this bacterium were received from Japan. This material was used in feeding and injection experiments, but there were no cases of death that could be traced to bacteria among the caterpillars.

There was a decrease in the abundance of the brown-tail moth fungus, *Entomophthora aulicae* Reich., which had been unusually abundant in 1930, although in 1931 it assumed greater epidemic proportions in certain localized spots. In this connection it may be mentioned that defoliation by the brown-tail moth was confined for the most part, as in recent years, to southwestern Maine, southeastern New Hampshire, and a small portion of northeastern Massachusetts. The infestation in New Hampshire was apparently much lighter, and in Maine somewhat lighter, in 1931 than in 1930.

ATTRACTANTS

Experiments in using the genitalia of female gipsy moths to attract the males were continued. The work done was with genitalia from females of different ages with various solvents and methods of exposure. It was found that for best results the virgin females should be from 24 to 36 hours old before the genitalia are removed. This was done by clipping the last three abdominal segments into xylene, benzene, toluene, and certain grades of gasoline. More practical use is being made of this method each year in locating isolated gipsy-moth infestations.

INSECTICIDES

Spraying and dusting experiments have been conducted for the control of the gipsy moth, the European pine shoot moth, the saddled prominent, the larch case-bearer, and *Epinotia nanana* Treitschke, and tests with sprays have been carried on against the beech scale and the elm leaf beetle. Hydrocyanic acid gas fumigation and the submergence of infested material in hot water have also been tried for the purpose of killing hibernating satin-moth larvae on nursery stock.

Barium fluosilicate and cryolite were tried as sprays in controlling the gipsy moth, but were not found to be so efficient as lead arsenate.

Laboratory experiments to ascertain the toxicity of lead arsenate and certain other insecticides were continued. Detailed tests were run with various dilutions, and the amount of poison consumed and the length of time required to kill were recorded. The experiments indicate that the proportion of lead arsenate now generally used in New England in sprays for controlling the gipsy moth can be considerably reduced, and field experiments have also been conducted which indicate similar results.

A fair degree of control against the European pine shoot moth was obtained by spraying with lead arsenate at the rate of 6 pounds to 100 gallons of water, with fish oil added as an adhesive. The saddled prominent was easily controlled with the same poison at the rate of 4 pounds to 100 gallons of water with the usual amount of fish oil added, and experiments with *Epinotia nanana*, to whose life history and habits some attention has also been given, indicated that it could be quite effectively controlled by spraying with the poison at the rate of 5 or 6 pounds to 100 gallons of water, with fish oil added. The experiments with the elm leaf beetle indicate that if fish oil is added to a lead arsenate spray, applied sufficiently early, the foliage will be protected throughout the season against injury by both adults and larvæ.

During the summer and fall of 1931 considerable time was spent in various sections of the New England States searching for the beech scale. Three distinct areas where infestations occurred were found: One in Boston and vicinity, one in the north-shore section of Massachusetts, and one in Maine.

In continued tests with substances that might increase the adherence of poison dusts, talc, ferric oxide, bentonite, and casein glue were again among the substances giving the best results. Lead oxide, Portland cement, and dry paste were also in this class.

Experiments having to do with foliage injury have also been continued. When applied alone, calcium arsenate was more soluble, adhered much less satisfactorily, and caused more injury than did lead arsenate. Hydrated lime did not decrease injury to foliage by arsenicals but decreased the adherence of lead arsenate. A ferrous sulphate-lime-lead arsenate mixture reduced the solubility and burning by lead arsenate and increased its adherence. When Bordeaux mixture was added to lead arsenate, Paris green, or calcium arsenate, the solubility of the arsenical was reduced and the adherence increased.

INSECTS AFFECTING STORED PRODUCTS

The work on insects affecting stored products is conducted under the general direction of E. A. Back.

DRIED-FRUIT INSECTS

As evidence of practical results following the development of investigations of dried-fruit insects, 168 units of fumigable space are now in use in and around the Fresno, Calif., area. The bureau has been largely concerned, in an advisory capacity, with this development.

Tests have been made of the efficacy of the commonly available fumigants, as well as ethyl formate, carbon dioxide with nitrogen in vacuum, and ethylene oxide beneath asphalt-coated canvas for fumigating dried figs. A new use for the ethylene oxide-carbon dioxide mixture was found when it was learned that one-quarter ounce of a mixture of ethylene oxide and unconsolidated carbon dioxide in proportions of 1 to 9, placed in 25-pound boxes of raisins, was adequate to kill all test insects at a cost of about 20 cents per ton of material. This new method is a variation of the individual-pack method of fumigating raisins in the packing line with ethyl formate.

A bait consisting of a fermenting water solution of malt sirup, previously found useful in codling-moth studies, was used successfully for capturing adults of dried-fruit Lepidoptera in vineyards, fig orchards, and storage plants between May and early November. The baits made it possible to secure much new and valuable information about seasonal prevalence of moths infesting dried fruits and their parasites. Baits were made in the proportion of one-half pint of malt sirup to 1 gallon of water and were changed twice a week. About 30 per cent, or more than 100,000 insects, attracted by the baits, were raisin moths.

Examination of samples of muscat and Malaga raisins showed that infestation was light before the trays bearing the fruit were stacked in the vineyards (done after drying was well advanced) but that samples from fruit that was protected in stacks from the direct heat of the sun were heavily infested, the muscat at the rate of about 28,000 larvæ per ton and the Malaga at the rate of about 71,000 larvæ per ton. The Sultanina (Thompson Seedless) samples were lightly infested.

Samples from three orchards showed that the infestation of moth larvae was exceedingly low in figs picked from trees, indicating that the raisin moth and others begin to infest the fruit at a later stage, since figs in boxes at ranch drying yards were heavily infested.

The comparative size of the overwintering population of the dried-fruit beetle was determined, as during the three preceding years, by the use of special traps baited with fermenting dried peaches. Between February 17 and May 19 about 31,868 nitidulid beetles were captured, and of these 60 per cent were the dried-fruit beetle. A prediction of light to medium abundance of these beetles in the season's fig crop, based on the relatively small size of the surviving overwintering population, proved to be a reliable forecast of the general situation.

Studies of the morphology and biology of various dried-fruit insects and repellents are under way. Progress reports were prepared and read before the Dried Fruit Association of California, Annual Institute of Fig Growers (Fresno, November 6), and the Dried Fruit Conference, University of California (May 8). A publication on fig insects in California was made available during the year.

INSECTS AFFECTING CURED TOBACCO

The large-scale fumigation of tobacco storages, involving about 8,000,000 cubic feet of warehouse space and about $10,500,000 worth of tobacco, mentioned in last year's report, has been repeated, with the result that much new information on dosage and effect upon the cigarette beetle (*Lasioderma serricorne* Fab.) and the tobacco moth (*Ephestia elutella* Hbn.) has been secured. Furthermore, through cooperation with firms conducting fumigations not included in the experimental program of the department, much added information of practical value has been secured. Large-scale fumigations are still in progress, and it is hoped to have accumulated by the end of the 1932 season sufficient information so that definite recommendations for control can be issued.

Intensive studies of the biology of both the cigarette beetle and the tobacco moth are in progress. To meet the demand for information regarding the newly destructive tobacco moth, a special publication has been prepared.

An additional infestation of the tobacco moth was discovered June 3, 1932, in a tobacco warehouse in Portsmouth, Va. Only five adult moths and no infested tobacco were found. The warehouse was immediately fumigated by the owners, and it is hoped that the infestation was killed out.

The department has the hearty cooperation in these investigations of the Tobacco Association of the United States.

FLOUR-MILL INSECTS

During the past year headquarters for the investigation of insects affecting flour mills were moved from Manhattan, Kans., to Kansas City, Mo. The work was conducted very much along the lines reported upon for 1931. Studies of the biology of the flour beetles *Tribolium confusum* Duv. and *T. ferrugineum* Fab. have been completed and the results prepared for publication.

Presumably because a vast amount of grain was carried over from the 1930 crop and milled in 1931, the insect condition in flour mills in 1931 was said to be the worst in the milling history of the Southwest. This situation, however, was promptly met by fumigation. Studies to determine the results of fumigations conducted under varying conditions as to fumigant, dosage, weather, and preparation of mill and machinery added greatly to an understanding of past failures to obtain desired results. Special effort has been made to determine, by repeated examinations of flour samples from various parts of milling equipment, those factors that hasten or postpone reinfestation of the mill following a satisfactory treatment by heat or fumigation.

BEAN WEEVILS

The investigation of the common bean weevil and the cowpea weevil was continued, with headquarters at Modesto, Calif. Due to low market prices,

which resulted in a large hold over of beans and cowpeas in warehouses and on the farms, and an unusually hot summer, there was an increase of about 34.5 per cent in the number of consignments received from farms that showed weevil infestation. The percentages of consignments showing infestation on arrival at the various warehouses during September and October, 1931, ranged from a minimum of 29.3 per cent to 100 per cent, with a general average of 64.7 per cent for 3,532 samples from 18 warehouses. While the percentage of infested samples representing farm deliveries at the warehouse was high, the percentage of infested beans and cowpeas making up the samples was very low. Infested deliveries were fumigated. Efforts to reduce field infestation by means of warehouse inspections and fumigations, coupled with improved storage conditions on the farm, have not to date yielded as promising results as anticipated.

PEA WEEVIL

The investigation of the pea weevil, started during July, 1930, at Corvallis, Oreg., was extended more intensively to the Palouse area of Idaho and Washington by the establishment of a substation at Moscow, Idaho, during August, 1932. Conditions in the Palouse area being far different from those in the Willamette Valley of Oregon where the data presented in last year's report were obtained, special studies about Moscow have been made during the past year concerning the relationship between harvest loss and weevil infestation. Harvest loss is important in the control of the pea weevil, for each weevily pea lost permits one more weevil to enter hibernation. It was found that in harvesting one 90-acre field, showing 30.2 per cent infestation, 2,194,114 peas were lost per acre, while on an adjacent 45-acre field, showing 50 per cent infestation, 1,169,043 peas per acre were lost. It was estimated that on these two fields the loss of seed due to shattering made it theoretically possible for 85,938,570 weevils to escape and find winter hibernating quarters.

A study was made of the amount of loss of peas that resulted from different methods of harvesting. The maximum loss per acre was found to be 50 per cent of the possible yield on a field, harvested by the combine method, from which the peas actually harvested amounted to 690 pounds per acre. The minimum loss was 7 per cent on a field yielding 1,428 pounds per acre, harvested by the combine. The average loss for 20 fields examined was 33 per cent of the possible yield; the loss on 11 fields averaged 29 per cent; the loss on 6 fields harvested by mower, rake, and stationary thresher averaged 32 per cent; whereas the loss on 3 fields harvested by other methods averaged 38 per cent.

Mortality studies indicated a maximum mortality of 74.6 per cent and a minimum of 20.2 per cent among weevils in shattered peas left in the field. When the seeds were within the pods the mortality varied from 2 to 22.3 per cent. Studies of mortality under varying conditions of hibernation are still in progress.

Experiments affecting control by burning stubble and straw left on the field by the combine, airplane dusting of fields with a substance poisonous to the adult weevil, deep plowing and disking, and the use of trap strips of early planted peas are under way, and extensive biological studies have been started both in Oregon and Idaho.

INSECTS AFFECTING STORED GRAIN

Investigations during the past year have been confined almost entirely to experimental control measures. It was found that an excellent distribution of chloropicrin could be obtained in an elevator bin by allowing the chloropicrin to drop into the grain stream as it entered the elevator bin. This method of application gave a perfect kill of grain weevils planted in the bin when 2 pounds of chloropicrin per 1,000 bushels of grain were used. Contrary to expectation, the discomfort of handling small quantities of grain so treated was not great.

Preliminary tests were conducted with a mixture of 1 part of ethylene oxide and 9 parts of carbon dioxide available for purchase in steel cylinders. The fumigant was applied directly from the cylinder to the grain stream entering the elevator bin. A portion of the grain stream was made to pass through a section of galvanized-iron piping into which the fumigant was sprayed. A dosage of 60 pounds of the fumigant per 1,000 bushels gave an almost perfect kill of grain weevils. The expense, at present, of this fumi-

gant applied in this manner is too great to make its use practical. Tests with propylene dichloride as a grain fumigant did not result satisfactorily.

Eggs of the Angoumois grain moth, the Indian meal moth, and the Mediterranean flour moth were exposed for 3, 6, and 24 hours, respectively, in air-tight 1-liter flasks containing 1 gram of paradichlorobenzene crystals at 82° F. Many eggs survived the 3-hour exposure, but none survived exposure for 6 and 24 hours. Adults of *Tribolium confusum* and *Sitophilus oryza* L. were unable to survive 1 hour's exposure to this amount of paradichlorobenzene at 90°, and all larvæ of *T. confusum* succumb after exposure for 5 hours, and all larvæ of the Mediterranean flour moth after exposure for 2 hours.

In order to meet numerous inquiries, corn infested with weevils and stored in cribs on the farm was treated with carbon monoxide gas from the exhaust of an automobile. As expected, the tests demonstrated that while carbon monoxide gas will kill such warm-bodied animals as rats and mice infesting cribs, it is of no value in killing grain weevils.

HOUSEHOLD INSECTS

Carpet beetles, especially *Anthrenus vorax* Csy., have been unusually troublesome and destructive in the District of Columbia during the past year. Their presence in apartment houses, often among the finest in the city, has caused concern to property owners, and has been the basis for lease cancellations. The department has attempted to show that owners of buildings are not necessarily at fault, or responsible, if household pests occur in new apartments shortly after their occupancy. However, treatments applied by property owners, as well as the experiments conducted by the department, are adding slowly to the information available concerning control of household insects.

INSECTS AFFECTING CONFECTIONS AND NUT MEATS

Insects affecting bagged peanuts in the shell can be controlled satisfactorily provided the warehouse is of tight construction. Insects in unshelled peanuts in sacks were nearly all killed when fumigated with hydrocyanic acid gas at the rate of 2 pounds of sodium cyanide per 1,000 cubic feet of space. The peanuts absorbed so much gas that it was necessary to enter the warehouse in the morning, after it had been closed for the night, with caution until the space had been reventilated.

In vault fumigation of bagged unshelled peanuts, a dosage of 25 pounds per 1,000 cubic feet of a mixture of 1 part of ethylene oxide to 9 parts of carbon dioxide for 24 hours gave a satisfactory kill of nut-infesting insects. Observations made by commercial firms indicate that in addition to its insecticidal effect, the ethylene oxide-carbon dioxide mixture retards the development of molds in nut meats for a considerable time.

INSECTS AFFECTING WOODWORK OF BUILDINGS

The practical importance of insects affecting woodwork of all sorts, particularly white ants, or termites, is evidenced by the 1,650 instances of damage brought to the attention of the department during the past year. Exaggerated accounts of termite damage and worthless or unproven remedies exploited by commercial operators have led the department to issue press notices warning the public that structural repairs are the only permanent remedial measures. Investigations have shown that even in the far South the danger of collapse of buildings because of termite damage is remote.

Experiments in termite-proofing of buildings, involving tests of various chemicals used for poisoning the soil and impregnating natural or composition woods, are in progress. Of special interest are those being conducted in cooperation with the Forest Products Laboratory on Barro Colorado Island, Canal Zone, Panama, in which structures large enough for rest houses are used.

A third progress report on the international termite exposure tests being conducted simultaneously in Australia, Hawaii, Panama, and South Africa was presented (January, 1932) before the annual meeting of the American Wood Preservers' Association. Cooperation with the termite investigations committee of the University of California has been continued and certain portions of the final report of the committee have been prepared by the department.

Studies on the biology of the Lyctus and anobiid powder-post beetles, as well as the wharf borer (*Nacerdes melanura* L.), and the old house borer (*Hylotrupes bajulus* L.) have been continued during the year and data assembled for

publication. In cooperation with the Naval Research Laboratory studies on the practicability of microphones—based on new principles—for field use in detecting wood borers in wood have been carried on. Microphones developed by certain commercial laboratories have not proved practical for such field use.

INSECTS AFFECTING MAN AND ANIMALS

Investigations of insects affecting man and animals have been continued under the direction of F. C. Bishopp.

SCREW-WORM FLY AND OTHER BLOWFLIES

The principal activity under this head has been the continuation of the large-scale range trapping experiment in Menard County, Tex. The area serviced by 661 flytraps comprises 154,879 acres. The results of the trapping are checked month by month by comparison with a similar area comprising 144,860 acres in which no traps are used. The abundance of all species of flies in the trapped area has been reduced approximately 70 per cent as compared with the untrapped area. Likewise the number of screw-worm cases in animals in the trapped area has been reduced approximately 51 per cent as compared with the untrapped area. A systematic study of all screw-worm cases in the two areas is being made, with a view to determine the predisposing causes of screw-worm injury in all classes of domestic animals within the territory in question. It is believed that such information will furnish the basis for recommendations for changes in range practice which will prevent an appreciable percentage of screw-worm cases.

Studies of the many factors affecting the efficiency of our standard flytraps have been continued, as have also those relating to the development of larger traps designed to reduce the labor required to service the standard traps and to dispose of carcasses on the range, and to encourage the development of parasites and other enemies of the screw worm.

Directed from the Uvalde, Tex., laboratory, a survey to determine the distribution and regional and seasonal abundance of the various parasites and predators attacking the screw worm and other blowflies has been undertaken. Parasite status jars were exposed in many parts of the country in cooperation with other workers in the Division of Insects Affecting Man and Animals. This survey has shown certain parasites to be rather widely distributed, while others are very much restricted in their geographical range. It has also indicated that the larval parasites *Alysia ridibunda* Say and *Xyalosema* spp. may be utilized in screw-worm control. The relationship of most of the parasites and predators to the screw-worm problem is little understood, but these field surveys and laboratory experiments are providing much useful information along this line.

CATTLE GRUBS

Cooperation with the Bureau of Animal Industry in area-control experiments has been continued. New insecticides for killing grubs in the backs of cattle have been tested and considerable biological data secured. Recent experimental work having shown that copper fed to insects has a tendency to prevent formation of fat bodies, and thus interfere with normal development, a test has been made of the effect upon grubs of feeding a moderate amount of copper in the form of copper sulphate to infested animals. The amount of copper in both the cattle and the grubs was increased considerably above the normal, with no apparent effect on either.

The idea is widely held that sprays commonly used against various flies which annoy cattle are effective against cattle grubs. Experiments were conducted on dairy cattle with two of the types of oil sprays most commonly used. These sprays were applied once each day. Half of each herd was left unsprayed as a check. The following spring there was no apparent reduction in the number of grubs in the group which had been sprayed.

Investigations relative to the natural control of cattle grubs in the Red River Valley of the North indicate that the presence of an excess of soil moisture is the important factor responsible for the scarcity of cattle grubs in this area. This moisture condition is brought about largely by the heavy soil types and level land characteristic of the area.

HORSE BOTS

Biological studies of the three species of horse bots prevalent in the Middle West has been under way during the past year, and informal cooperation with State authorities in Illinois and Iowa in conducting county control campaigns has been maintained.

REINDEER INSECTS

The investigation of the reindeer bots which cause heavy losses to the reindeer industry in Alaska was temporarily discontinued at the close of the calendar year 1931 because of curtailment in available funds. This work has been under way for three seasons in cooperation with the Territory of Alaska. Much necessary information has been gained as to the life history and habits of the two species of flies concerned. No satisfactory method of control, however, has been developed as yet. Tests of insecticides applied by high-pressure spray guns did not give very encouraging results, and the treatment of the practically wild herds at the proper time presents many practical difficulties. Experiments with artificial shade as a method of preventing infestation likewise proved this idea impractical.

Pasture-rotation tests were carried out on a moderate scale, but it was found impossible to control all animals by herding, and apparently the flies can travel long distances in search of the deer.

This problem is of so much importance to the owners of reindeer herds that further efforts to find a solution should be made when economic conditions are more favorable.

EYE GNATS

Considerable progress has been made in developing methods for control of eye gnats (*Hippelates* spp.) breeding in southeastern California, by modified cultural practices. In a previous report mention was made of the establishment of the fact that these pests breed promiscuously in decaying organic material. Since 1930 a large series of experimental plats have been maintained. Studies have been made on these plats during this period to determine the effect of different cultural methods and crops on the breeding of eye gnats. These studies indicate that a reduction in breeding as high as 75 to 90 per cent may be secured by cutting and raking vegetation from soil before it is plowed. At no time of the year or under any condition is there indicated to be any considerable number of eggs deposited in cultivated soils 10 days or more after soils are worked or after soils are firmed down. It is further indicated that heavy soiling crops can be turned under or heavy applications of manure made during January and February and the soil given shallow (2 to 3 inch) cultivation during the remainder of the year without inducing heavy eye-gnat breeding.

Experiments have been continued with types of traps and baits suitable for capturing the adult gnats. Liver, water, and urea has been found to make a cheap and effective bait. In cooperation with the local abatement association a series of gnat traps has been operated over a considerable area. This work has shown as a result a material decrease in the abundance of eye gnats and a marked reduction in the number of cases of eye diseases and the persistence of such cases as still occur. This benefit has been especially noticeable in the schools, where the eye trouble has seriously interfered with school work. A marked reduction in eye-gnat breeding has been apparent throughout the trapped area as compared with the same area which was trapped the previous year. It has been found that practically all of the gnats caught in the traps are females.

MOSQUITOES

The small field force attached to the laboratory at Portland, Oreg., has continued to push vigorously the biological and control studies of the mosquitoes of Oregon and Washington. So far as it has been possible to do so, surveys have been made of the areas most affected by these pests. In the vicinity of Portland the field survey of breeding areas was supplemented with observations and photographs from airplane. From these data rather accurate maps of the extensive mosquito-breeding places have been prepared.

To facilitate oiling and draining operations and to study the effect on mosquito breeding of removal of vegetation from over and around breeding areas, extensive clearing operations were carried out on the Columbia River bottoms in cooperation with the Portland Civic Emergency Committee. Some 1,800 acres of willow flats were cleared, utilizing "unemployed" labor to the extent of nearly 13,000 man-days. This operation was found to greatly reduce the extent of mosquito breeding, and oiling was greatly facilitated by it.

Various civic organizations in the two States have sought the advice and counsel of the laboratory staff concerning mosquito control. Wherever possible such requests have been complied with. Active cooperation with the Portland Chamber of Commerce in the local mosquito-control program has been maintained.

At the Orlando, Fla., laboratory a mosquito survey of Florida has been started and information gathered on the occurrence and abundance of the different species encountered, with special reference to the anopheline mosquitoes. The biological studies of the pest mosquito *Mansonia perturbans* Walk. have been continued, and an article dealing with the facts determined to date has been published. Officers of a number of State and county mosquito-control organizations have been aided by demonstrations by bureau workers as to how and where to find the larvæ of this species. Heretofore mosquito-control agencies have been greatly handicapped by their inability to find the breeding places of this troublesome pest.

Considerable attention has been given to the testing of various insecticides designed to kill mosquito larvæ in their breeding places. The tests of colloidal Paris green indicate that an abundance of food in the water keeps the larvæ from ingesting a lethal amount of the poison, and that newly hatched larvæ are more susceptible than older ones. Tests of various Paris green mixtures have been made on several species of mosquito larvæ in the Northwest, but none of them has given results which indicate practical value.

The mosquito problem on the Delaware-Maryland-Virginia peninsula and on the west side of Chesapeake Bay is so serious as to interfere with the proper development of that territory. At the request of citizens of the three States concerned a survey of mosquito conditions was begun during the summer of 1932 in cooperation with the experiment stations of these States. The plan is to determine by means of mechanical traps what mosquitoes are most prevalent in different districts, and their seasonal occurrence. During the summer at least 25 different species of mosquitoes have been captured and much has been learned of their relative importance.

SAND FLIES

Substantial progress has been made in the investigations of sand-fly (*Culicoides* spp.) habits, life history, and control. Some of the more important findings are now in course of publication. It has been determined that breeding of some of the more troublesome species is concentrated in shady areas of marsh and that the larvæ congregate in drainage ditches which do not function properly. Where ditches are well drained, the action of the tides appears to carry the larvæ out to sea. This indicates the possibility of correlating drainage operations for salt-marsh mosquito control with sand-fly control work. The larvæ of sand flies require from six months to a year for development at Charleston, S. C. The pupal period ranges from four to seven days. The long period required for larval development suggests that long intervals may be allowed to elapse between treatments for control.

During the year a large sprayer truck has been used in testing insecticides in control of sand flies breeding in the salt marshes near Charleston. A waste product obtained during the process of creosoting pine timber has been found to be toxic to sand-fly larvæ. It consists of water and pine sap with a small content of creosote oil. It is known as creosoted pine sap. It kills sand-fly larvæ almost instantly in dilutions of 1 to 1,500 parts of water. By adding 5 per cent of crude phenols the toxicity is increased so that sand-fly larvæ are killed with dilutions of approximately 1 part in 10,000 parts of salt water. This modification of the creosoted pine sap is known as phenolized pine sap. It will be useful in locations where it is difficult to transport large quantities of creosoted pine sap.

At the close of the fiscal year the laboratory for the investigation of sand flies was moved from Charleston, S. C., to Savannah, Ga., as it is believed that the latter location furnishes better facilities for the continued study of the problem.

THE USE OF BLOWFLY MAGGOTS IN BONE SURGERY

The discovery a few years ago that certain species of blowfly maggots could be used to advantage in the treatment of osteomyelitis (human bone infection) enlarged our conception of the useful properties of insects. A matter of such vital importance to the health of several thousand sufferers from this disease in the United States laid upon us the obligation to investigate thoroughly such properties of insects as could be used in the healing of wounds and to determine the proper and safe method for such use. A laboratory for the study of this subject has been established in Washington.

One of the first considerations was to devise a satisfactory method of rearing maggots in the laboratory throughout the year, and another important objective was to produce maggots free from bacteria so they could be used safely in human wounds. Both of these objectives have now been attained. The information necessary to produce sterile maggots throughout the year has been made available to biological and medical technicians through mimeographed circulars and an article published in a technical journal. Requests are received at times from other laboratories for aid in their rearing problems. Technicians visit the laboratory and are shown in detail the cultural methods which have been developed. The laboratory is equipped to produce sterile maggots on a moderate scale for continuous experimental use in either human or animal wounds or in technical research.

Experiments upon methods of increasing the productivity of flies by means of suitable foods and physical conditions are now being made. The laboratory has been meeting the occasional requests of other laboratories for flies to enable them to start up colonies of their own. In order to keep a supply on hand in cold storage it has been necessary to find out the most suitable temperature and life-history stage for holding over. Experimental results show that prepupæ can be held in the refrigerator at 40° to 42° F. for three to four months and upon removal will develop into satisfactory colonies of flies.

Substantial progress has been made in a study of how blowfly maggots bring about disinfection of the wound in treatment of osteomyelitis. Under the maggot treatment disinfection takes place rapidly. The laboratory investigations indicate that the maggots are able to destroy bacteria by digestion and that destruction takes place mainly in the mid-stomach. Maggots were also found to hasten disinfection of the wound through their scavengering effect by consuming large quantities of the necrotic tissue in the wound.

BEE CULTURE

The Division of Bee Culture is under the direction of James I. Hambleton, with headquarters at Somerset, Md., and with three field laboratories—the intermountain laboratory, Laramie, Wyo.; the southern laboratory, Baton Rouge, La.; and the Pacific coast laboratory, Davis, Calif.

The work of this division covers all phases of apiary management and honey and wax production, and also bees as aids to crop production in their rôle as cross-fertilizers of many plants.

TECHNICAL STUDIES

The artificial fertilization of queen bees reported on last year has been continued and the technic much improved. This type of fertilization now seems to be fully successful and is believed to represent an important contribution to the commercial breeding of the honeybee and also particularly by giving exactness to hybridization work having as its object the production of stronger and more productive bee types. As a preliminary to such hybridizing a careful study has been made of the available characteristics of bees, including the color pattern of workers, drones, and queens, and also important anatomical details, such as tongue lengths and other measurements.

A study was made at Somerset of the secretion of nectar by the tuliptree or tulip poplar (*Liriodendron tulipifera*). Daily observations were made from May 17 to 28, and the average amount of nectar per blossom was found to be 1.54 grams. With this figure as a basis, a rough estimate indicated that a tulip-poplar tree 12 to 14 years old would secrete in the neighborhood of 8½ pounds of nectar during the blossoming period. The nectar is apparently available before the blossom opens and the bees enter the partly open blossoms

and at this time unquestionably do a more thorough job of pollinating the flower than would be the case in a fully opened blossom. The moisture and solids in the nectar were calculated throughout the period of the observation.

POLLINATION STUDIES

Studies of pollination of clover by the honeybee have been continued from last year at Holgate, Ohio, in cooperation with the Bureau of Plant Industry, particular attention being given to the second bloom of red clover. It was found that a majority of the honeybees working on this plant were collecting pollen rather than nectar and also that, with the exception of the early morning hours, the number of honeybees in any given field of red clover in the vicinity of the experimental colonies greatly outnumbered all other insects. That the honeybee is of great importance in the pollination of red clover would seem to be clearly indicated.

The specific use of package or small bee colonies for the pollination of orchard fruits was discussed in some detail last year, and in view of the demand for bees for such pollination a study was undertaken in California and Oregon of the results of pollination, both from the standpoint of the orchard grower—namely, fruit production—and from the standpoint of the beekeeper in relation to cost and losses involved in the rental of colonies. One outcome was the determination that in some of the important fruit-producing districts of California and Oregon one colony to every 7½ acres of fruit is satisfactory, whereas it was previously thought necessary to have one colony to an acre of fruit.

DISEASES OF BEES

The study of the possible carriage of bee diseases of the foulbrood type in honey has been continued. In connection with this work a spore-forming bacillus has been isolated and cultured which is believed to be the causative organism in a new disease prevalent in parts of Florida and Georgia. Morphologically and culturally, this organism appears to be related to *Bacillus alvei*, the spore-bearing bacillus present in European foulbrood. In cooperation with the States of Florida and Georgia a temporary laboratory to study this new disease was established at Thomasville, Ga. It is proposed to call this disease parafoulbrood and the bacterium *Bacillus para-alvei*. Preliminary investigations indicate that it can be controlled by the same methods employed for American foulbrood.

An investigation has been started of an abnormal death of adult bees to which the term "paralysis" has been given. The indications are that it is an infectious disease transmittable by adult bees. Neither the food nor the queen appear to be directly responsible, nor apparently is the disease readily transmitted to healthy colonies by combs of brood or food stores, provided all infected adult bees are removed.

ECONOMIC STUDIES

A study of the cost of production of honey, undertaken in 1930–31, has been discontinued owing to shortage of funds. Although incomplete, these studies have yielded valuable information relative to the effectiveness and cost of different methods of wintering bees, disease control, and other cost figures which up to this time have been practically unavailable.

The Pacific Coast Bee Culture Field Laboratory, Davis, Calif., in cooperation with the Giannini Foundation of the University of California, has practically completed a survey of the production, distribution, and consumption of California honey. It includes data on the exports of honey from the Pacific Coast and intermountain States and also exports from Hawaii. Data have also been obtained on the production and distribution of honey from such regions as Canada, New Zealand, South America, and Central America which comes into competition with the Pacific coast honey in world markets.

MISCELLANEOUS

The accumulation of data has been continued on the distribution and importance of honey plants in the Southern States. Similar records also are being collected for the principal honey-producing plants in the United States, classified according to regions.

Studies of flight range of bees have been previously reported, based on a small number of colonies only. During the past year such studies have included a considerable number of colonies. In one experiment some 35 colonies were located approximately a mile and a half from the source of nectar, while some 31 colonies were located so as to be completely surrounded to a distance of a mile or more by the source of nectar. The first series made an average gain of approximately 43 pounds, while those located in the midst of the source of honey showed an average gain of some 72 pounds. This type of work was repeated with similar results at another apiary.

The poisoning of bees by buckeye on the Pacific coast has been referred to in other reports. A method of minimizing such losses, suggested by the Pacific Coast Bee Culture Field Laboratory, is now being tried by a number of commercial beekeepers. It seems that there are about 15,000,000 acres upon which buckeye, which is detrimental to bees because of the resulting depopulation of colonies, grows abundantly. On the other hand, there is evidence to indicate that in this vast area honey can be produced in commercial quantities; and, as indicating a means, it has already been found that certain hybrid bees appear resistant to the poison. Incidentally buckeye honey is not poisonous to humans.

TAXONOMY AND INTERRELATIONS OF INSECTS

TAXONOMY

The investigations under this unit have continued under the direction of Harold Morrison.

In previous reports I have called attention to the large amount of service work that is performed by specialists attached to this section, namely, the identifications of insects in all orders for all branches of the Government service, State experiment stations, colleges and universities, and other agencies and persons working with or interested in economic and other phases of insects. It may be pointed out again that the accurate or specific determination of any insect pest, new or old, is necessarily the first step in its investigation and is the key that opens up its relation to information and literature that may be available. The increase in demand for this type of work has been so pronounced during the past two years as to place a very heavy burden on the present staff, and has lessened the fundamental research work on insect classification which is much needed. It is realized that under present economic conditions the remedy for this situation must necessarily be postponed. As an indication of the volume of work of identification referred to for the fiscal year 1932, it may be noted that a total of 25,736 identifications were made during that year, as compared with 17,430 made during the fiscal year 1931.

Attention may also be called to the fact that the specialists in the different classes or groups of insects are called upon to give critical examination to bureau manuscripts for the purpose of checking on identifications of insects concerned, and particularly to insure the use of the latest scientific designations.

The fundamental research work of this section, namely, describing insects and preparing monographs of groups with tables facilitating identification, results every year in the publication, through appropriate scientific and technical channels within and outside the department, of a very large number of papers, totaling for the fiscal year 1932 some 31; and 27 additional papers have been completed.

INSECT PEST SURVEY AND PUBLIC RELATIONS

This work has continued under the direction of J. A. Hyslop.

INSECT PEST SURVEY

The insect pest survey, through collaboration with the official entomologists of the several States, our insular possessions, Canada, Mexico, Guatemala, Costa Rica, Cuba, Haiti, and Brazil, has continued to collect information on insect distribution and abundance throughout the United States and neighboring countries, and has issued each month to entomological and other agencies associated with entomological work a report on current insect conditions. It has furnished, also, individual information on specific pests to the workers of the Bureau of Entomology, the entomologists in 10 States, and the Bureau of Plant

Quarantine—information that has enabled them to decide on the relative importance of supposedly new pests.

During the fiscal year 1932 the survey received over 20,000 notes on domestic insect conditions. These added nearly 400 genera and 2,790 species to the 5,700 genera and 14,600 species already in the records. There have now been reported, as of more or less economic importance, over 17,000 species of insects representing 6,000 genera in this country alone. During the year there were added to the foreign insect pest record 7,800 notes, bringing this record up to 9,000 species in over 4,000 genera. The total file on June 30, 1932, contained 159,600 notes on 26,450 species of insect pests.

PUBLIC RELATIONS

The public relations project of this section, through three subject-matter specialists in entomology working in cooperation with the extension personnel of the several States, has organized fruit-spray services in four new States, and vegetable-spray service in two additional States. Campaigns have been started for the eradication, over limited areas, of horse botflies in Virginia, and assistance has been given to a state-wide campaign for the eradication of these pests in Iowa. The extension specialists of the bureau have assisted also in organizing a mosquito-eradication campaign to be carried on jointly with the States of Maryland, Delaware, and Virginia. This campaign does not contemplate the use of Federal funds or personnel.

Through this section the bureau has prepared material for film-strip lectures on insects, and during the year these have been taken with portable projectors to the States to be used in visual education on insect-pest control throughout much of the Cotton Belt and in some of the East Central States. The extension service of the bureau has further been instrumental in encouraging county agents and other extension workers in maintaining reference libraries of entomological bulletins, and has furnished these workers with lists of bulletins and sources of supply. A new outline plan of work has been carried to the States which has materially improved the subject-matter work in entomology. In the grasshopper-stricken Northwest, particularly in North Dakota, very material assistance has been rendered in the control campaigns and in organizing for this type of work for next year if later conditions indicate that such will be necessary.

INSECT PHYSIOLOGY AND TOXICOLOGY

The centralization of certain basic investigations, in the general field of physiology and toxicology of insects, at the Takoma Park, Md., station was referred to last year, and an outline was given of the different activities under this section. An important phase of the work has been the carrying out of tests on new insecticides prepared by the Bureau of Chemistry and Soils; also basic studies of the action of stomach poisons, of tropisms of insects, and research studies on insect nutrition. Some of the important results of this work are referred to below. This station has been under the general direction of Frank L. Campbell, who has been particularly concerned with the study of toxicology of stomach poisons and with the tests of various new insecticides. N. E. McIndoo has been conducting the studies on tropisms and sense organs of insects, and D. E. Fink on the metabolism of insects in relation to food elements and also studies on the distribution of arsenic in the bodies of insects as indicating where the toxic action takes place.

TESTS OF INSECTICIDES

The tests here reported refer to insecticides prepared by the Bureau of Chemistry and Soils.

Tests against house flies of alcoholic solutions of rotenone and 13 derivatives of it showed that rotenone was more toxic than these derivatives, that dihydrorotenone was nearly as toxic as rotenone, followed by rotenone hydrochloride and acetyl rotenone, and that the other 10 derivatives were relatively nontoxic.

Tests against the house fly of dusts of derris root and of rotenone showed that this species is killed by extremely small quantities of both dusts. Comparative tests of powdered derris root and of the same root from which rotenone, etc., had been extracted showed that thoroughly extracted root was not toxic to house flies. The method of dusting house flies developed for this

work was also applicable to the testing of pyrethrum powder and was given further study by one of the manufacturers of pyrethrum insecticides.

Comparative tests of alcoholic solutions of the pyrethrins and rotenone showed that the former has a more rapid effect on house flies, but that the insecticidal value of the latter is greater.

Rotenone when sprayed in alcoholic solution on house flies proved to act as a contact poison in a manner not yet understood. It had no effect on house flies when administered in suspension by mouth, nor did it have any effect in the vapor phase at room temperature.

Some of the foregoing results and all information available on the insecticidal value of rotenone were published in multigraphed form for the information of entomologists.

TOXICOLOGY OF STOMACH POISONS

The so-called sandwich method was used to study the effect of calcium hydroxide, calcium-casein spreader, precipitated sulphur, dry Bordeaux mixture, and hydrated ferric oxide on the toxicity of acid lead arsenate for the fourth-instar silkworm. No remarkable effect was produced by any of these substances. It is fairly certain, however, that calcium hydroxide and calcium-casein spreader increase the toxicity of acid lead arsenate when mixed with it in approximately equal proportions by weight. The indications are that precipitated sulphur may increase the toxicity of acid lead arsenate, and that dry Bordeaux mixture and hydrated ferric oxide may decrease it. Experiments were made by the sandwich method on the relative susceptibility to acid lead arsenate of the following caterpillars in the last instar: Eastern tent caterpillar (*Malacosoma americana* Fab.), fall webworm (*Hyphantria cunea* Drury), walnut caterpillar (*Datana integerrima* G. and R.), and the catalpa sphinx (*Ceratomia catalpae* Boisd.). With the median lethal dose of acid lead arsenate for the fourth-instar silkworm as the standard of comparison, it was found that the first two insects were less susceptible and the last two more susceptible to acid lead arsenate than the fourth-instar silkworm. It was also shown that, although the median lethal doses of acid lead arsenate and cuprous cyanide are different for the catalpa sphinx and the silkworm, their relative toxicity is about the same for each of these insects.

Following the completion of the foregoing work last fall, efforts were made without success to improve the sandwich method in various ways.

TROPISMS AND SENSE ORGANS OF INSECTS

Tests with three species of blowflies in a wooden olfactometer showed that the relative response of the flies to odors from various simple and complex aqueous solutions can be measured with considerable accuracy. By tests of fermenting and putrefying solutions from day to day, it was possible to follow the change in response of the flies to changing chemical conditions in the solutions. A manuscript on this subject was submitted for publication.

Histological studies of the sense organs of blowflies were made. No chemoreceptors were found on the tarsi. Special attention was given to the gustatory papillæ on the oral lobes.

In order to throw more light on the location of the chemoreceptors for odors, the wooden olfactometer was used to compare the response of normal blowflies to odors with those whose antennae had been wholly or partly amputated. No significant difference in response to a variety of odors was detected. Similar results were obtained when the maxillary palpi were amputated. It would seem that the sense organs concerned with response to odors are not located on the parts amputated.

Progress was made in the writing of a long manuscript on the tropisms and sense organs of Diptera.

Further studies were made of the preferences of potato beetles among four host plants: (1) Potato, (2) horse nettle, (3) bitter nightshade, and (4) tomato. The male beetles and the larvæ prefer horse nettle and the female beetles potato.

METABOLISM OF INSECTS

Analyses were made at intervals during the winter on the content of water, glucose, glycogen, fats, and proteins in the hibernating larvæ of the codling

moth and strawberry leaf roller. The results are too complicated to be given here. It was shown, however, that changes occur, particularly in glycogen content, during hibernation, indicating the utilization of stored carbohydrates in metabolism during the dormant period.

Experiments were made on the resistance of adults and larvæ of the Mexican bean beetle and of adult Colorado potato beetles to submersion. The respiratory metabolism, glucose, and glycogen content, and hydrogen-ion concentration of the blood of normal insects were compared with those of insects that had been submerged for various periods.

Considerable work was done with several species of insects on the distribution of lead and arsenic from lead arsenate in the bodies of the insects. A radioactive isotope of lead was used as an indicator to detect lead photographically in microtome sections of the insects and to measure it electroscopically.

NUTRITION OF INSECTS

Striking results have been obtained relating to the diet, and information has incidentally been acquired about the life history and behavior of the American cockroach and its reaction to stomach poisons. Many interesting questions have arisen, any one of which would be worthy of careful study. In cages containing unsatisfactory foods the occurrence of cannibalism affects the results. The attraction of moribund roaches for stronger roaches is so great that the American cockroach may be induced to eat poisons that it would not otherwise consume by mixing the poison with mashed roaches.

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